NOAA FISHERIES

Northwest Fisheries Science Center

11.2 NWFSC Research on Protected Rockfishes in Puget Sound

Protected Species Program Review

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May 6, 2015

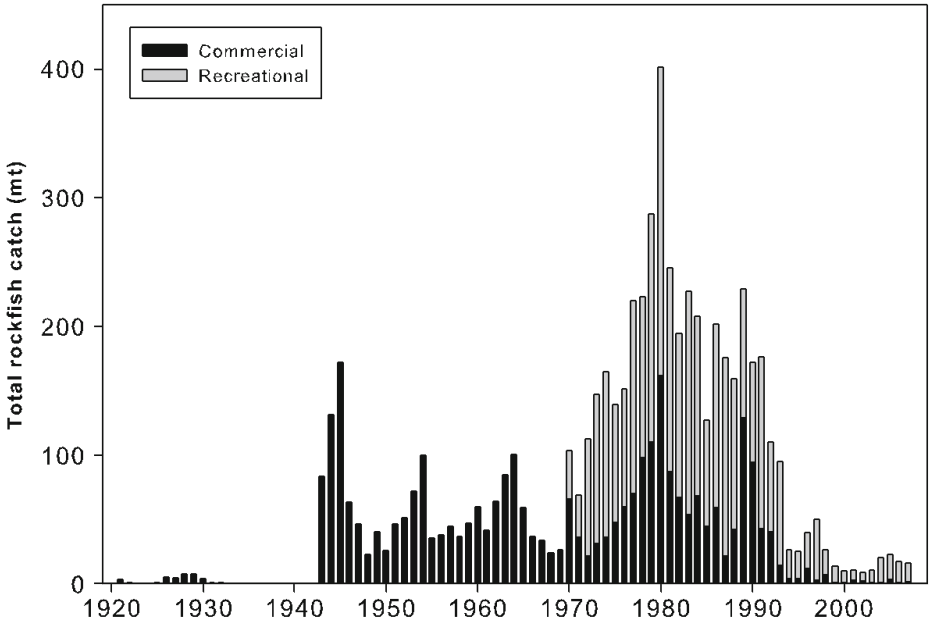
Rockfishes

- Scorpaeniformes: *Sebastes*
- Gonochores (2 sexes, no hermaphroditism)
- Live-bearing
  - Internal fertilization
  - Brood larvae
- Larval period of several months
- Iteroparous & Long-lived
  - Mature at 5-20 years, live ~20-120
- Episodic recruitment in many species
- Larger juveniles and adults are primarily pisivorous
- Tendency towards site attached behavior
- Tendency towards association with hard bottom

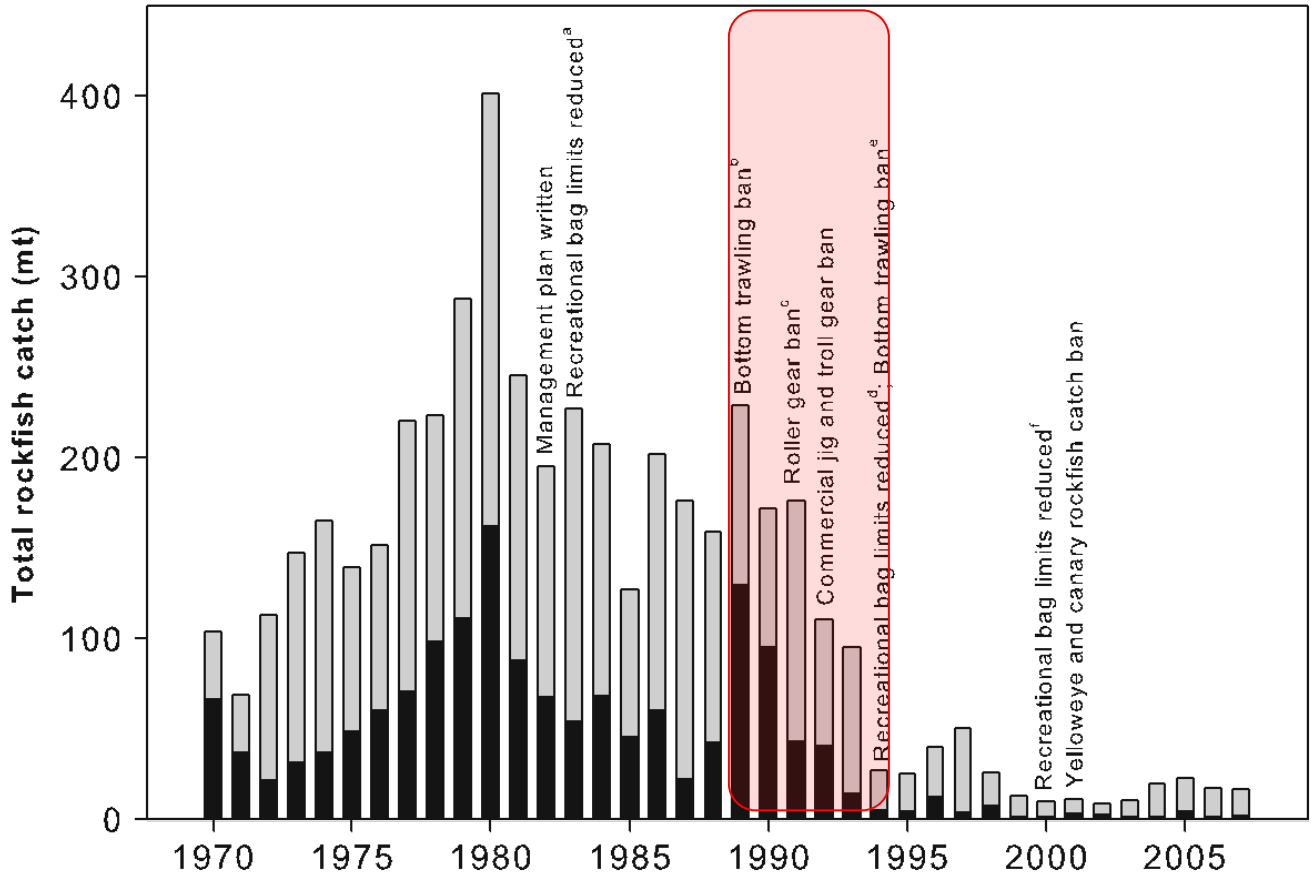
- ~70 spp on west coast
- ~28 spp in Puget Sound

Exploitation history of rockfishes in Puget Sound

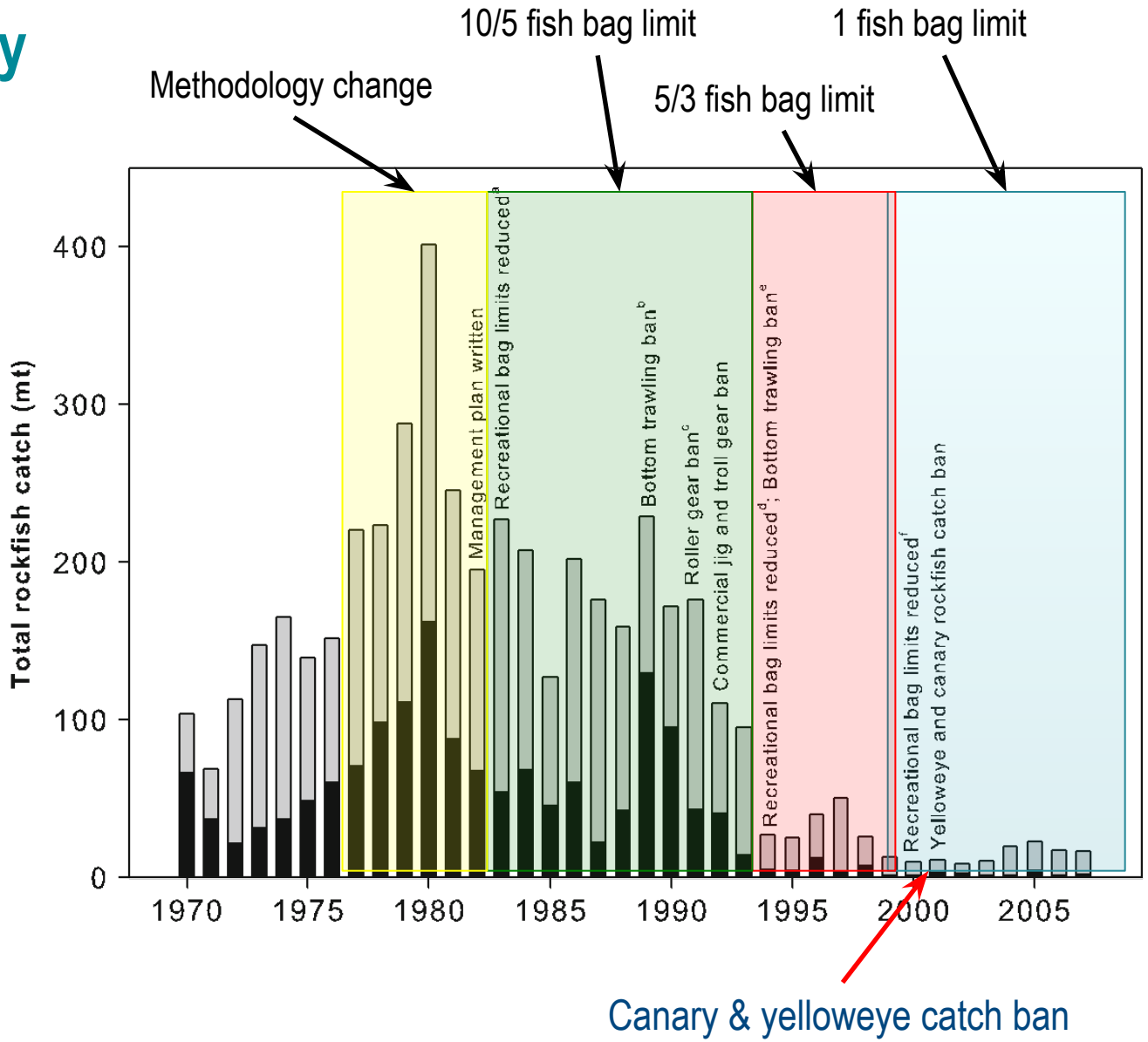
- Archaeological and ethnographic evidence of long history of use
  - “lunch” fishery
- Commercial catch really begins with WW2
- Recreational fishery increased in the 1980’s with reduced Salmon fishing
- No good recreational catch data prior to 1970’s



Regulatory changes for the commercial fishery



Regulatory Changes for recreational fishery

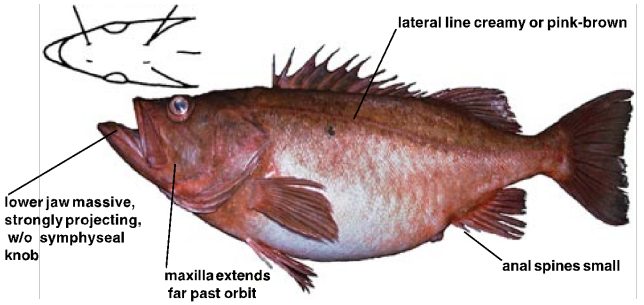


2010 Listing: 120 foot max depth limit for bottom fishing

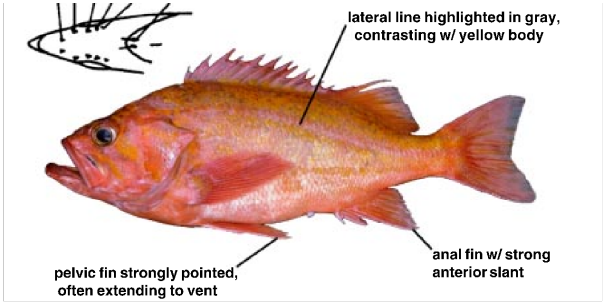
Highlights of the 2010 ESA listing

- 1999 Petition to list 14 spp
  - NMFS reviewed 3
    - Copper *S. caurinus*
    - Quillback *S. maliger*
    - Brown *S. auriculatus*
  - *Declined to list*

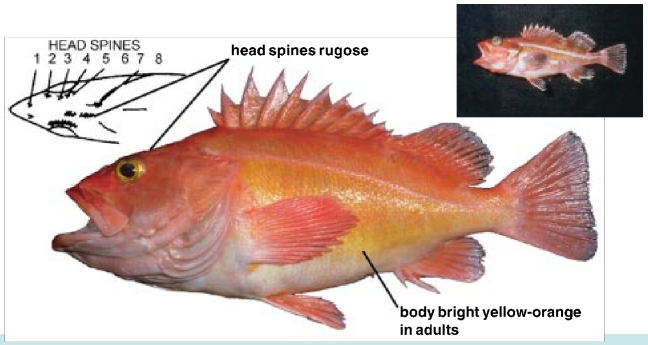
- 2007 Petition to list 11 spp
  - NMFS reviewed 5
    - Bocaccio *S. paucispinis*
    - Canary *S. pinniger*
    - Yelloweye *S. ruberrimus*
    - Greenstripe *S. elongatus*
    - Redstripe *S. proriger*
  - *Listed in 2010*
    - *Bocaccio – endangered*
    - *Canary – threatened*
    - *Yelloweye – threatened*



BOCACCIO *Sebastes paucispinis*



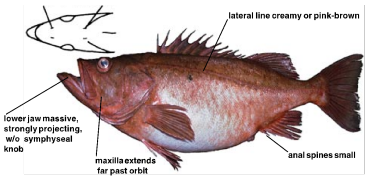
CANARY ROCKFISH *Sebastes pinniger*



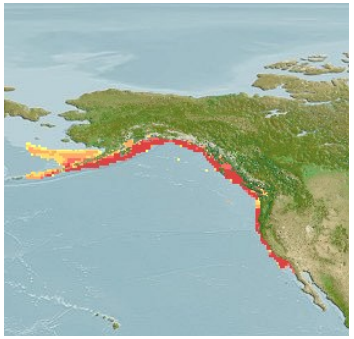
YELLOWEYE ROCKFISH *Sebastes ruberrimus*

Obligate life history slide

Bocaccio



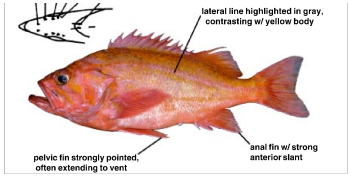
BOCACCIO *Sebastes paucispinis*



- 3 ½ month pelagic stage
- Larvae released Jan – Apr
- Settle to kelp, eelgrass and rocky reef
- Females mature at 54 – 61 cm; 4-8 yrs
- Max age 54 years, size 91 cm

- Adults at 50-250 m
- Generally rocky habitat

Canary



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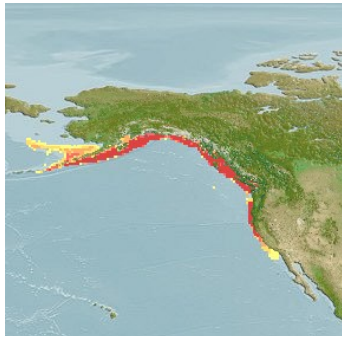
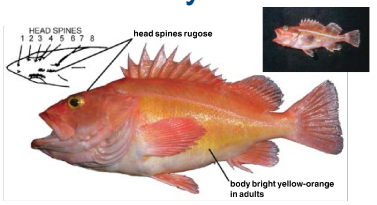


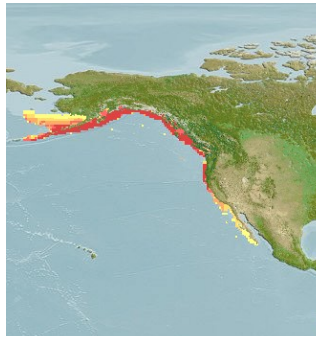
- 1-4 month pelagic stage
- Larvae release: peak Dec & Jan
- Settle to tide pools, rock, cobble, kelp & eelgrass
- Females mature at 35 – 45 cm; 4-9 yrs
- Max age 84 years, size 76 cm

- Adults at 50-100 m
- Generally rocky habitat

Yelloweye



YELLOWEYE ROCKFISH *Sebastes ruberrimus*



- 2 month pelagic stage
- Larvae released spring-summer
- Settle to shallow, high relief areas
- Females mature at 40 – 50 cm; 15-20 yrs
- Max age 118 years, size 91 cm

- Adults at 90-180 m
- Generally rocky habitat

Two criteria for ESA listings

1. Distinct Population Segment (DPS)?
    - Must be “discrete”
        - Separate from other populations based on physical, physiological, ecological or behavioral factors.
            - Genetics
            - Life history traits – e.g., site fidelity
            - Ecological features of the oceanic and terrestrial environment
        - Delimited by international governmental boundaries
    - Must be “significant”
        - Unique ecological setting
        - Loss would result in significant gap in the range of the taxon
        - Represents the only surviving natural occurrence
        - Differs markedly in its genetic characteristics

2010 BRT: *Probably* genetically distinct

Based on data from other places or species

Yelloweye in "inside" waters of Canada show evidence of being distinct from yelloweye in "outside" waters (Yamanaka et al. 2006, Siegle et al. 2013).

Copper, Brown and Quillback rockfish in Puget Sound are genetically distinct from outside waters (Seeb 1998, Buonaccorsi et al. 2002, 2005).

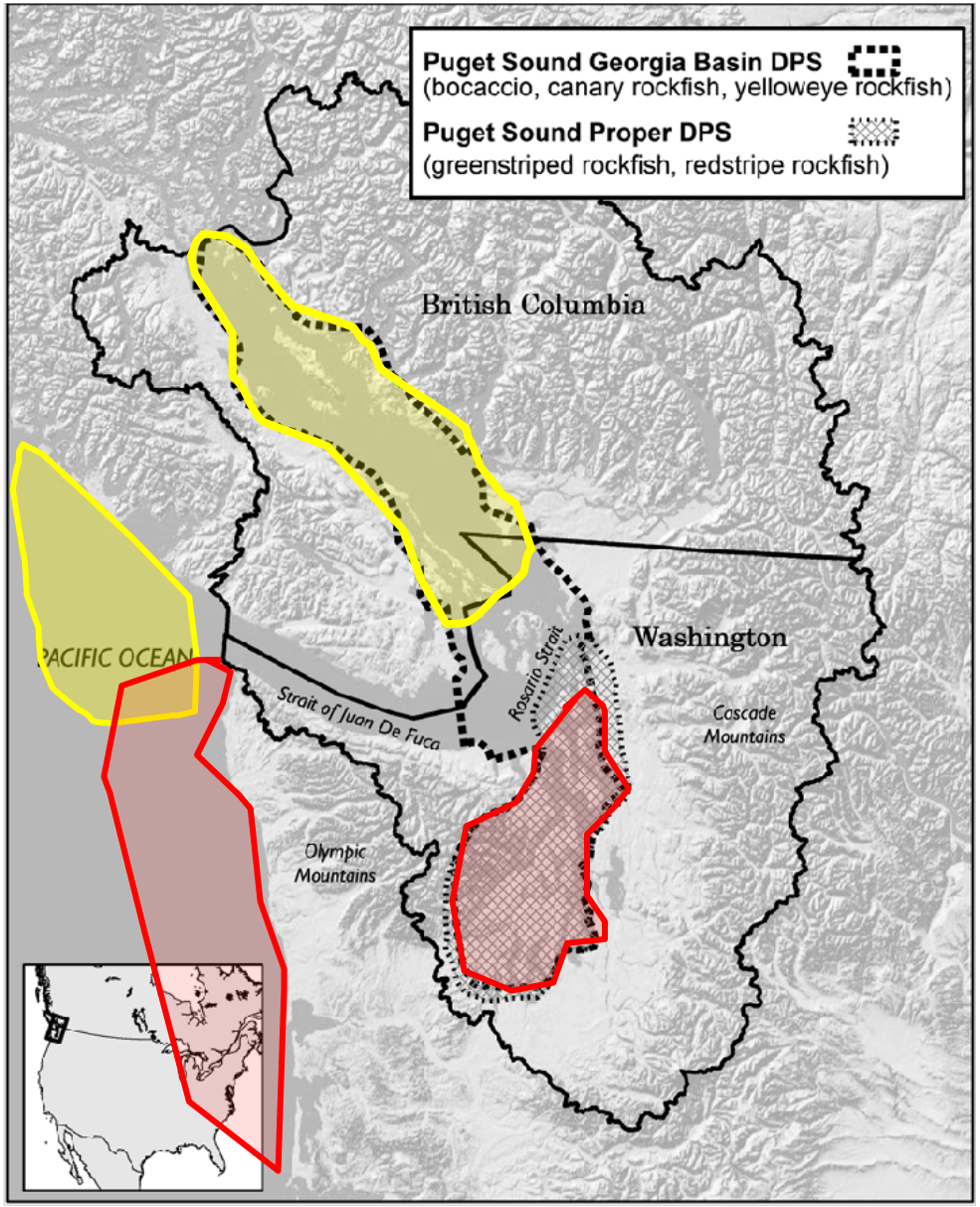


Figure 16. Map depicting the approximate DPS boundaries for the Georgia Basin/Puget Sound and PSP DPSs. Figure is for purposes of illustration only and should not be used to identify precise boundaries.

Features that make Puget Sound "unique"

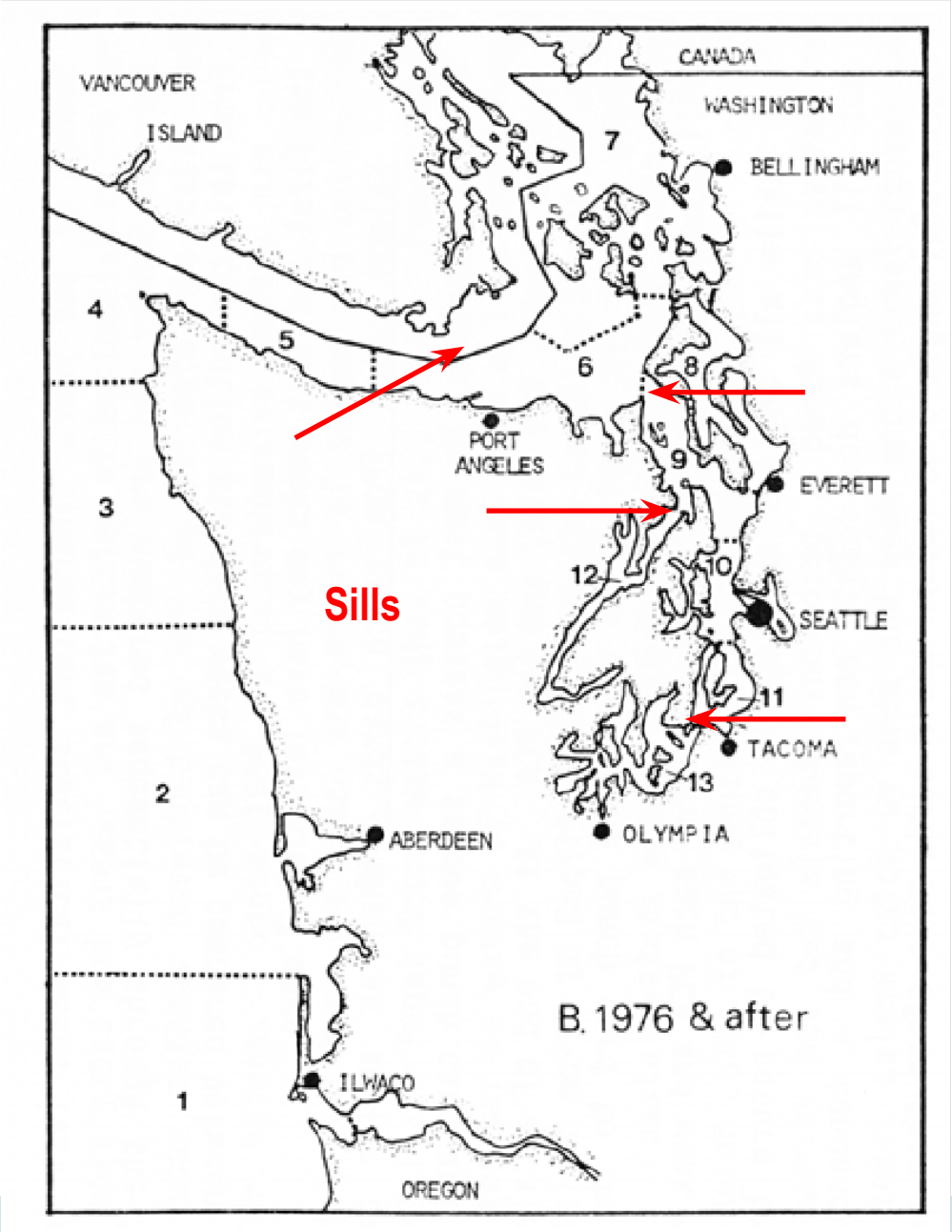
Glacial Fjord

Shallow sills
Narrow channels
High freshwater input
Strong stratification
Limited shallow water habitat

These all make PS…

….different from the rest of the California Current

✔Unique



Distinct Population Segment (DPS) for bocaccio, canary & yelloweye

2010 BRT report

Everyone agreed

Maybe out to here

BUT
this designation was based largely on biological information from other species or places other than the US part of the DPS

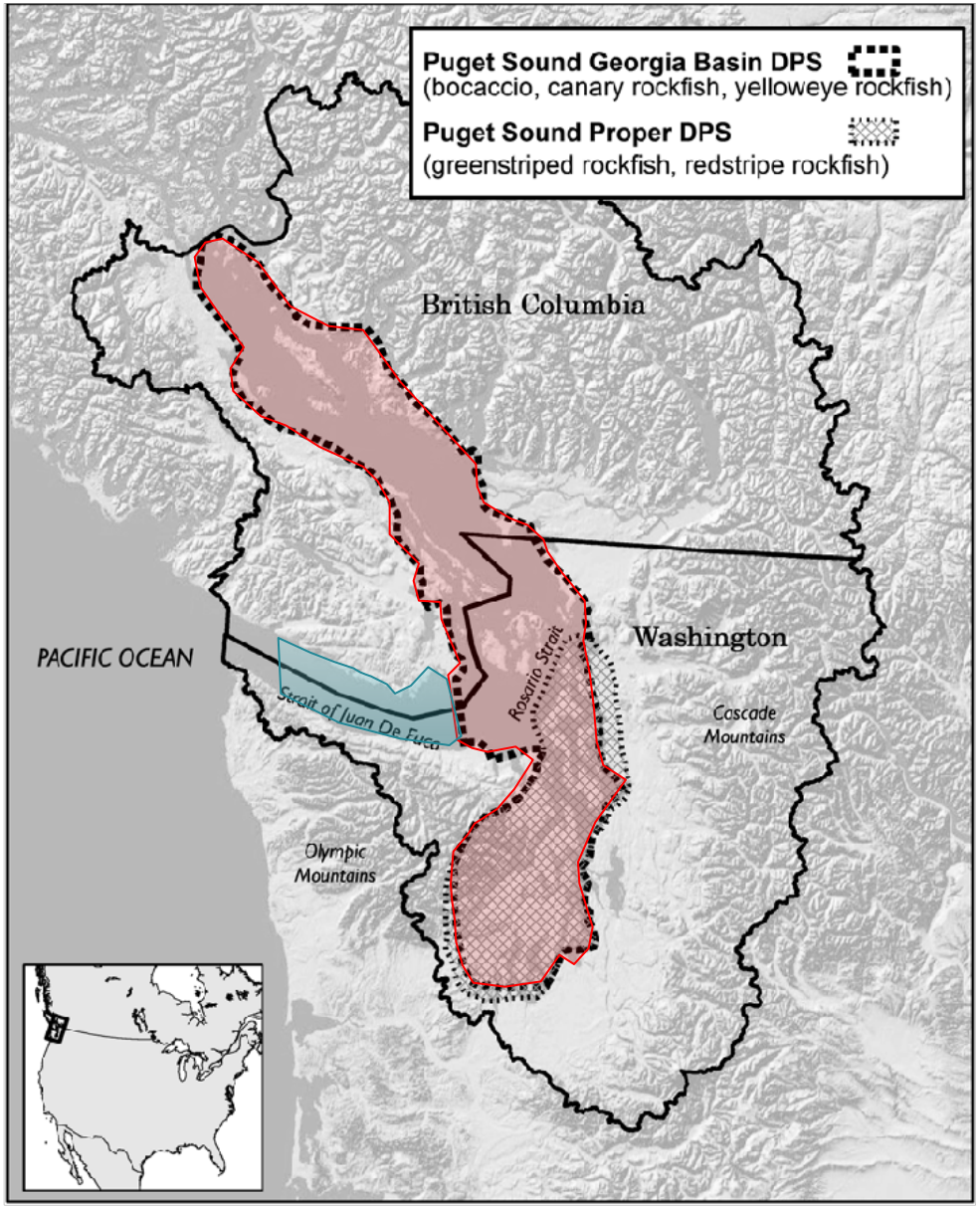


Figure 16. Map depicting the approximate DPS boundaries for the Georgia Basin/Puget Sound and PSP DPSs. Figure is for purposes of illustration only and should not be used to identify precise boundaries.

Two criteria for ESA listings

2. Level of extinction risk
   - Endangered or Threatened or Not at Risk?
     - **Relative or absolute abundance**
     - **Trends in abundance**
     - Environmental and Anthropogenic pressures
     - Threats to genetic integrity
     - **Size frequency distributions**

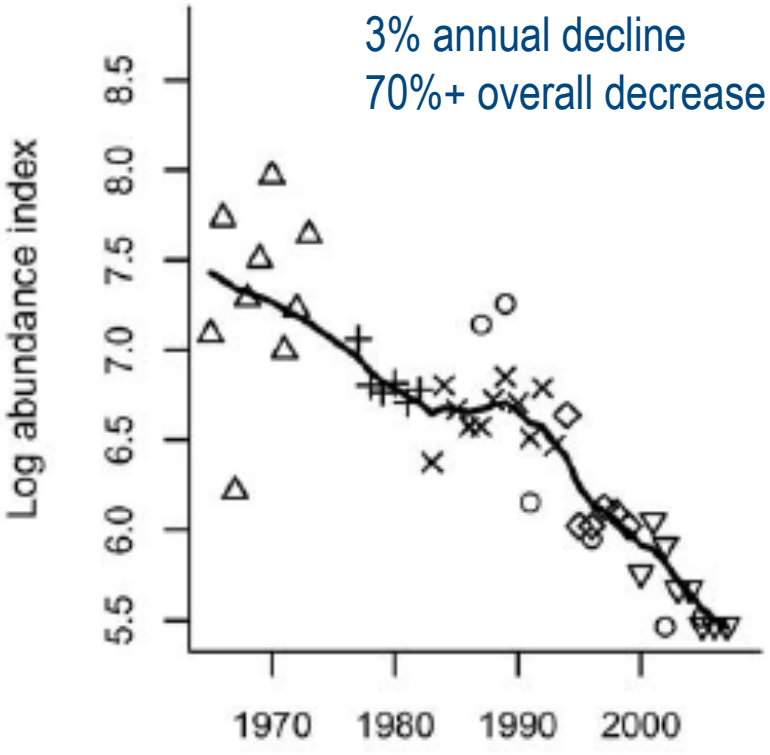
Rationale 2010 BRT for statistical analysis

- Three data sets
  - WDFW recreational survey data
  - REEF scuba survey data
  - WDFW Trawl survey
- BUT very few data on the petitioned species
- Some species composition data
- Use TOTAL ROCKFISH to estimate a general trend
- Compare to species composition data
  - % listed increases = not decreasing as fast as TOTAL
  - % listed constant = decreasing at same rate as TOTAL
  - % listed decreases = decreasing faster than TOTAL

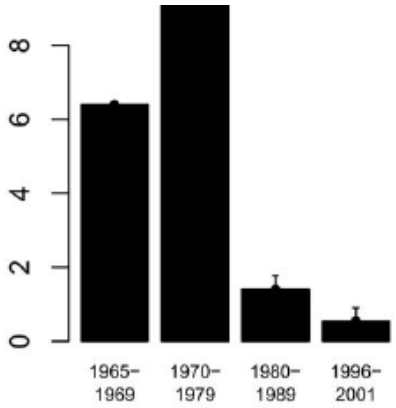
Rockfish populations in decline
2010 BRT Report

Rockfish in Puget Sound

3% annual decline
70%+ overall decrease

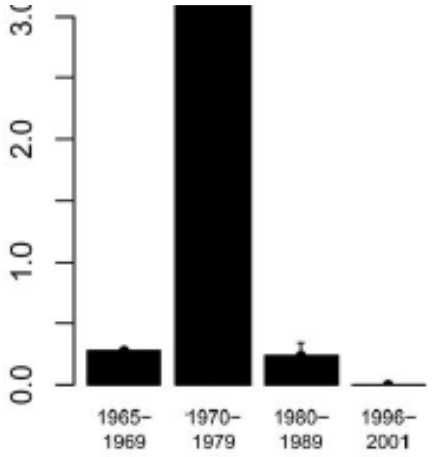


Canary rockfish

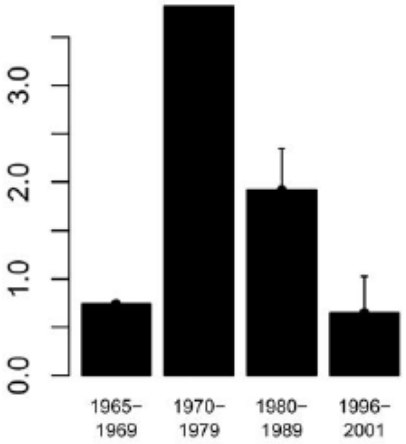


Proportion that were
canary
bocaccio
yelloweye

Bocaccio



Yelloweye rockfish



Primary threats: harvest and dissolved 0_2

Table 28. Results of qualitative ranking by the Puget Sound rockfish BRT of severity of threats for five DPSs. The median (with standard deviation) is shown for each threat type. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. Members not voting mark severity of threat as "unknown."

		Habitat Modification				Fisheries		
DPS		Nearshore	Dissolved oxygen	Contaminant	Nutrients	Commercial	Recreational	Disease
Bocaccio	Median	3	4	3.5	3	4	5	Unknown
	SD	0.707107	1.30247	0.744024	1	0.64087	0.755929	
Yelloweye	Median	3	3	3	3	4	4	Unknown
	SD	0.755929	1.246423	1.035098	1	1.30247	0.517549	
Canary	Median	3	4	3.5	3	4	4	Unknown
	SD	0.707107	1.30247	0.744024	1	1.06066	0.517549	
Redstripe	Median	2	3.5	3	3	2.5	2.5	Unknown
	SD	0.834523	1.28174	1.125992	1	1.164965	1.164965	
Greenstriped	Median	2	3	3	3	2.5	2.5	Unknown
	SD	1.139626	1.296538	1.307323	1.069045	1.51174	1.899376	

120 ft max depth bottom fishing

DPS (table continues horizontally)		Predation	Other				
			Competition	Derelict gear	Invasives	Climate	Hatchery
Bocaccio	Median	3	3	2.5	3.5	3.5	4
	SD	0.894427	1.414214	1.21106	0.957427	1.264911	0.408248
Yelloweye	Median	3	3.5	3.5	3.5	4	4
	SD	0.752773	1.47196	0.816497	0.957427	1.032796	0.408248
Canary	Median	1.5	3	2.5	3.5	2	2
	SD	0.816497	1.414214	1.21106	0.957427	1.032796	1.032796
Redstripe	Median	1.5	3	2.5	3.5	2	2.5
	SD	0.816497	1.414214	1.21106	0.957427	1.169045	1.048809
Greenstriped	Median	1.5	3	2.5	3.5	2	2
	SD	0.979759	0.921485	0.969312	1.359062	1.194626	1.540314

NWFSC research projects:

- Population Genetics
  - Do PS populations differ from coastal ones?
- Population trends of rockfishes in Puget Sound
  - Rate of decline?
  - Spatial structure?
  - Recent trends?

NWFSC research projects:

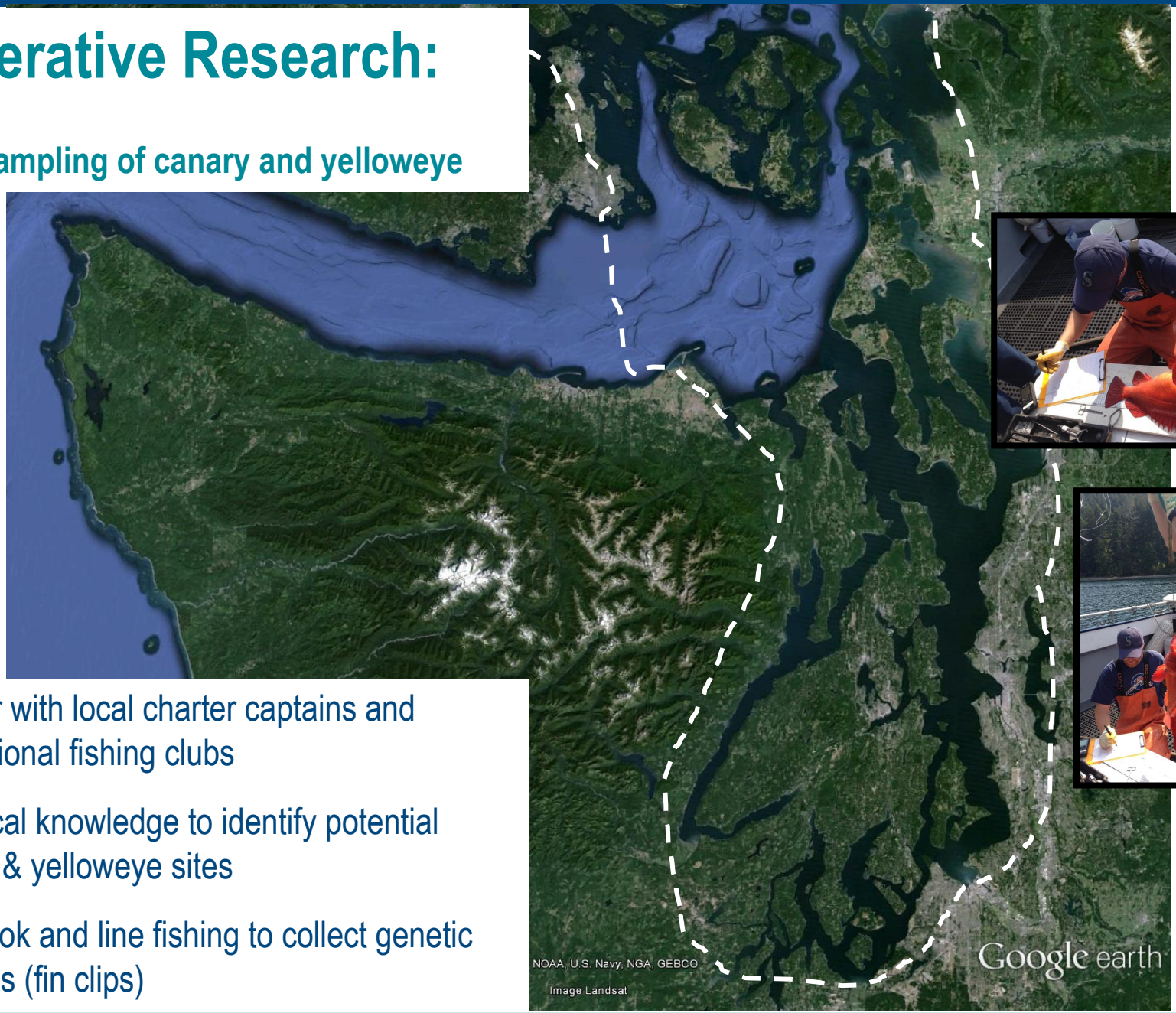
- Population Genetics
  - Do PS populations differ from coastal ones?

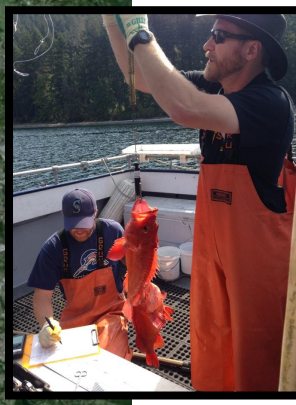
Is there a Puget Sound DPS?

- Population trends of rockfishes in Puget Sound
  - Rate of decline?
  - Spatial structure?
  - Recent trends?

Cooperative Research:

Genetic sampling of canary and yelloweye



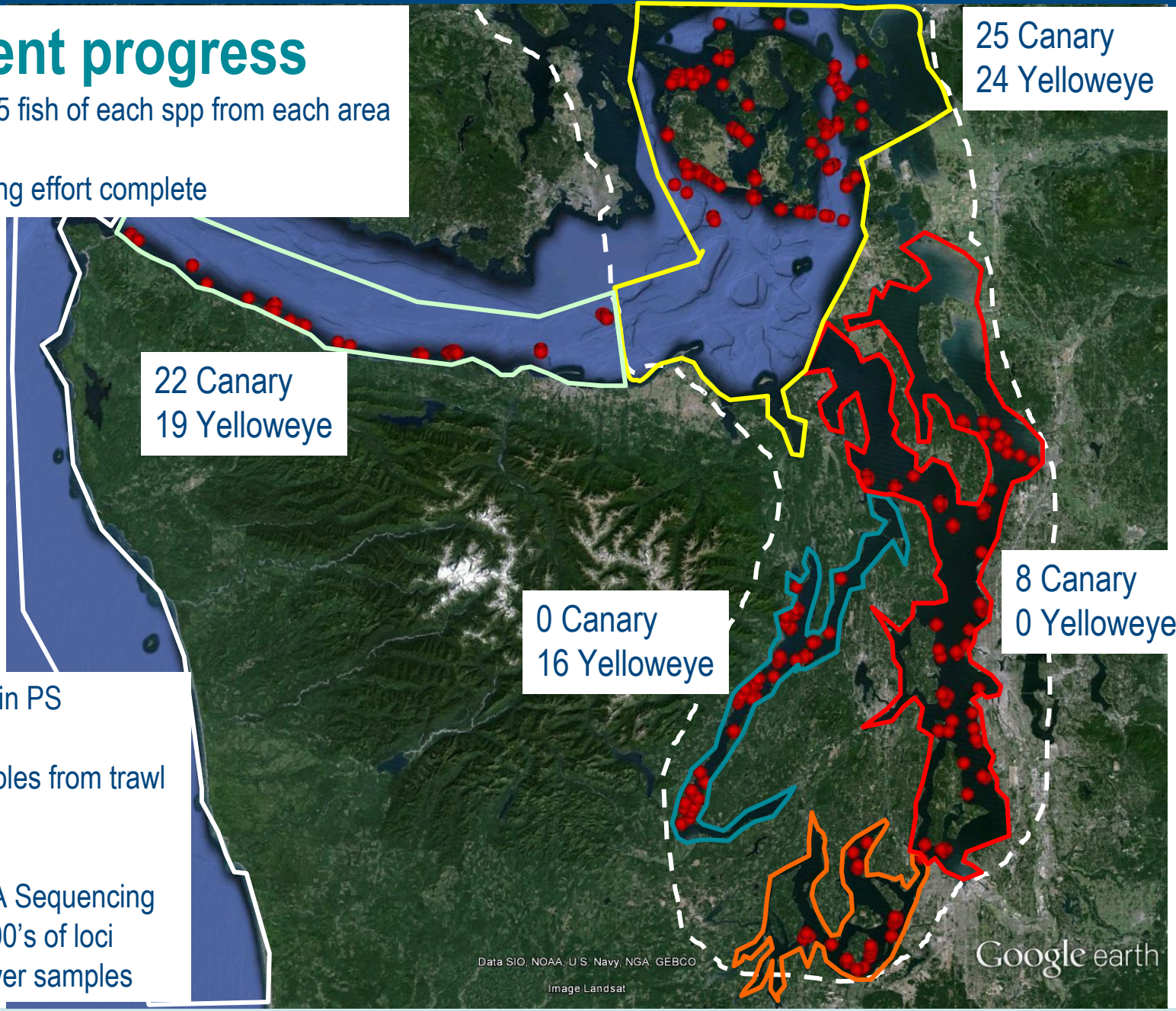


- Partner with local charter captains and recreational fishing clubs
- Use local knowledge to identify potential canary & yelloweye sites
- Use hook and line fishing to collect genetic samples (fin clips)

Current progress

Target = 15 fish of each spp from each area

~ half fishing effort complete



Fish 5 areas in PS

Coastal samples from trawl survey

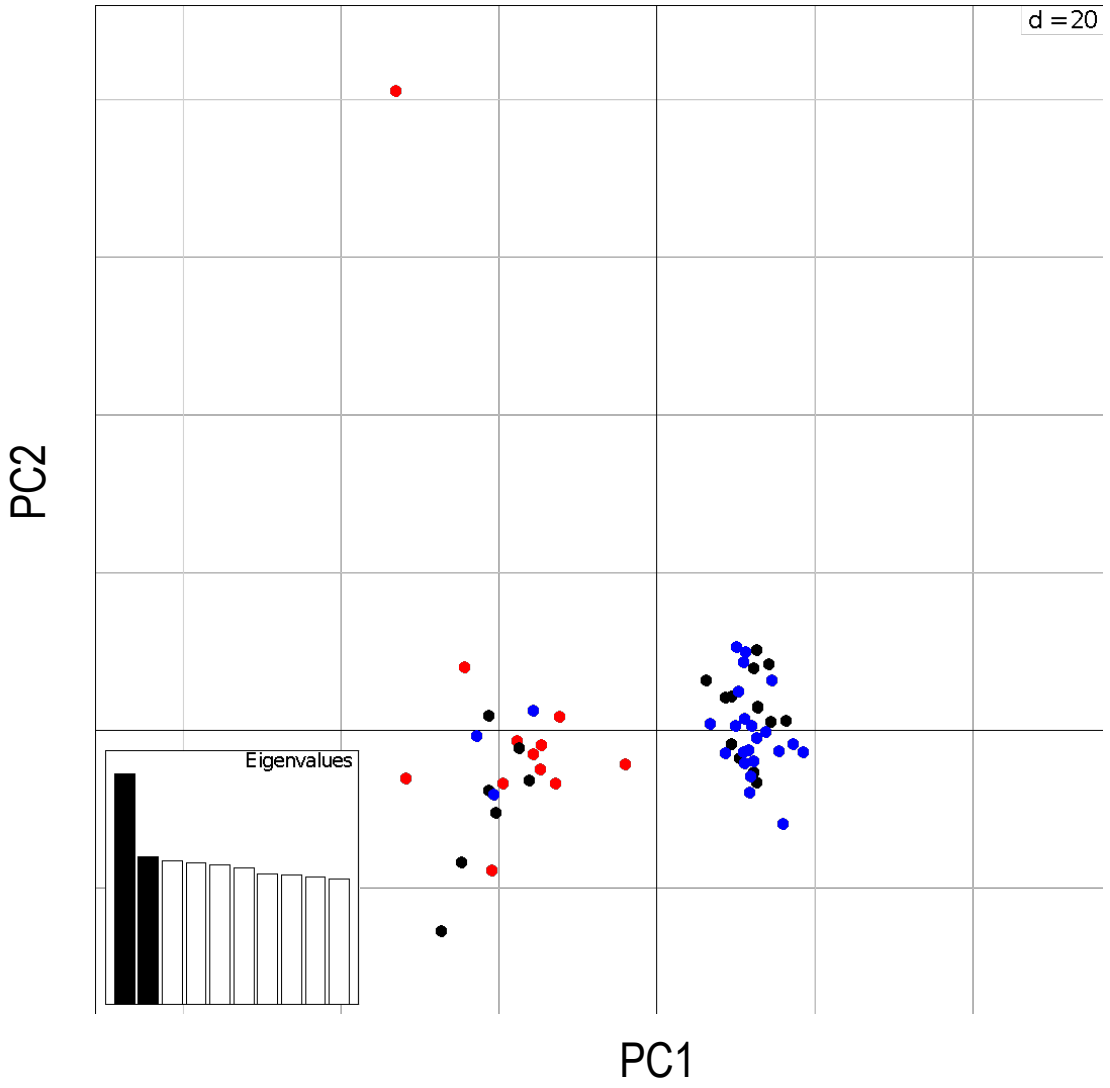
RADseq DNA Sequencing

- Uses 1000's of loci
- Need fewer samples

Preliminary genetics results

Yelloweye rockfish
(7745 SNPs)

- Coastal (n = 12)
- Canadian (n = 21)
- Puget Sound (n = 25)

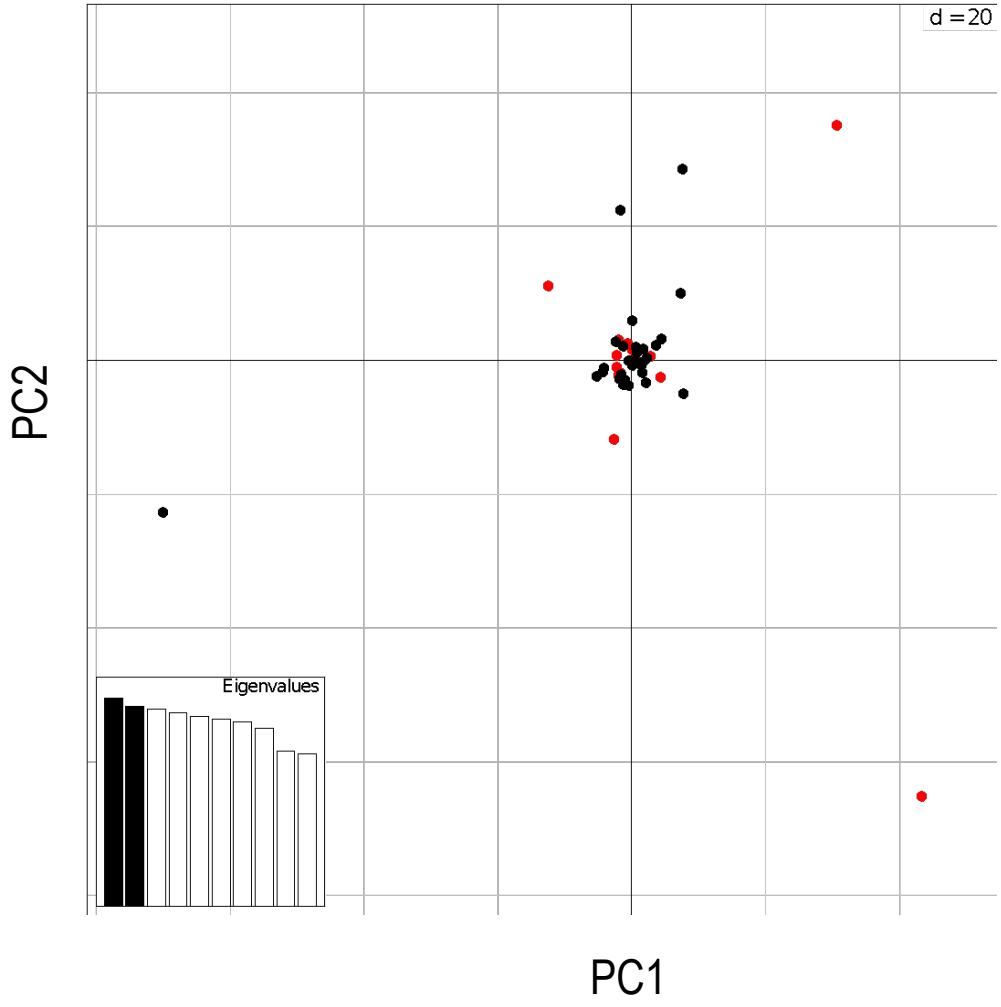


Principal coordinates analysis
all individuals, all genotypes

Preliminary genetics results

Canary rockfish
(6999 SNPs)

- Coastal (n = 15)
- Puget Sound (n = 31)



Does not support DPS

NWFSC research projects:

- Population Genetics
  - Do PS populations differ from coastal ones?

- Population trends of rockfishes in Puget Sound
  - Rate of decline?
  - Spatial structure?
  - Recent trends?

Extinction risk

DPS delineation

Recovery?

Multivariate Autoregressive State Space Models (MARSS)

$$\mathbf{x}_t = \mathbf{B}_t\mathbf{x}_{t-1} + \mathbf{u}_t + \mathbf{C}_t\mathbf{c}_t + \mathbf{w}_t$$

Process model

u = population growth rate*

x_t = the state

x_{t-1} = autoregressive

w = process error

$$\mathbf{y}_t = \mathbf{Z}_t\mathbf{x}_t + \mathbf{a}_t + \mathbf{D}_t\mathbf{d}_t + \mathbf{v}_t$$

Observation model

y = the data

Z = space, time series

a = a scaling term

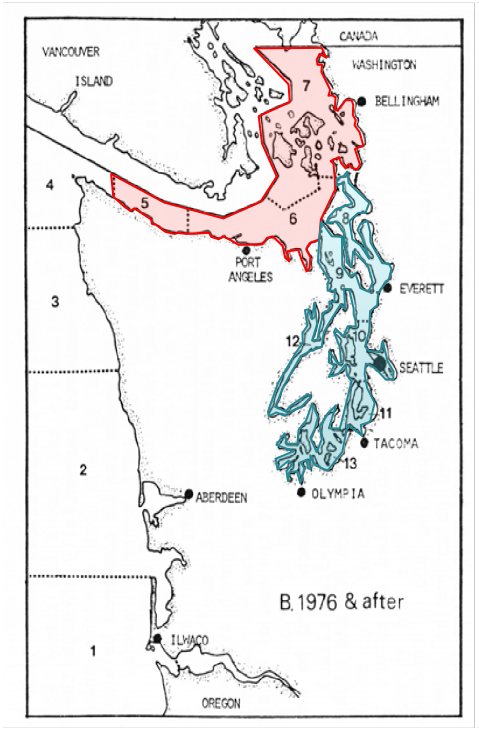
v = observation error

* With log(y) data the process model = discrete-time Gompertz model

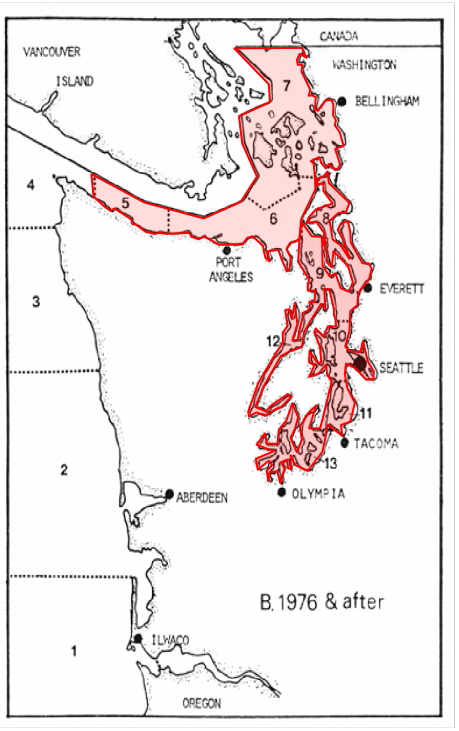
2010 BRT Analysis looked at two spatial options:

Different population trends between regions or one in all Puget Sound?

By Region

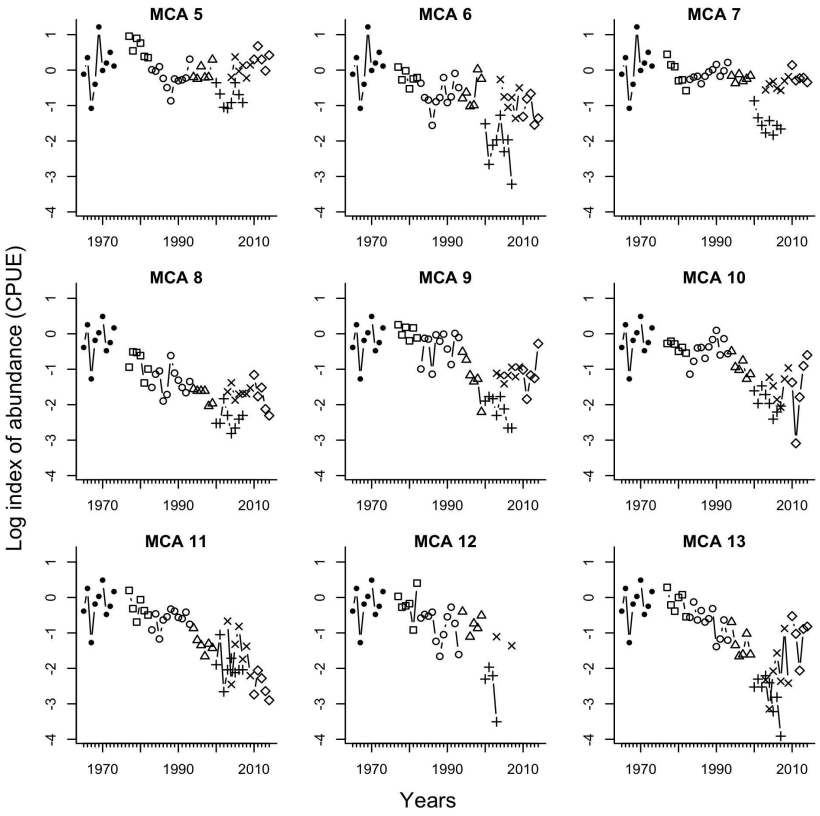


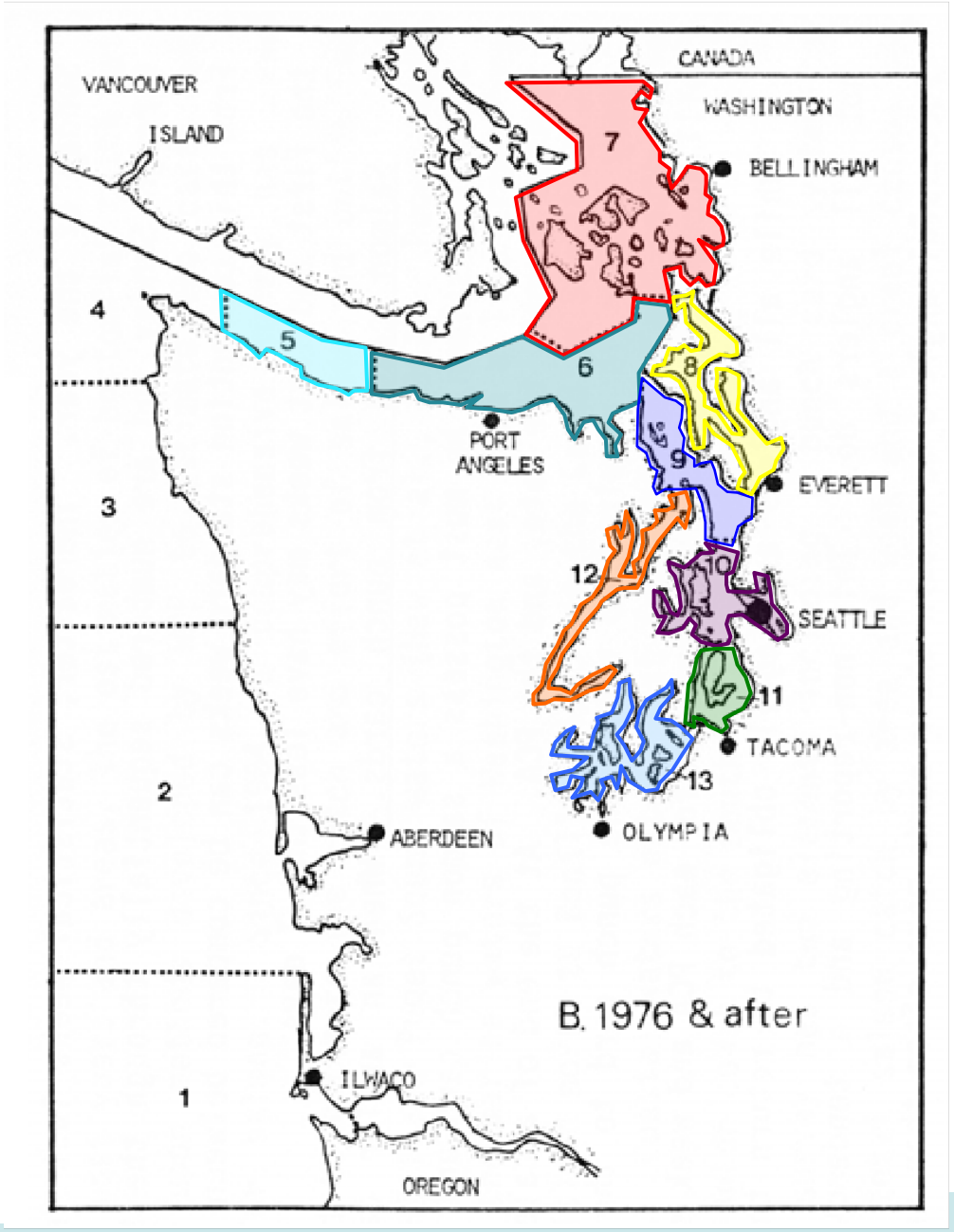
All Puget Sound



Management Conservation Areas

9 MCAs within “Greater Puget Sound”

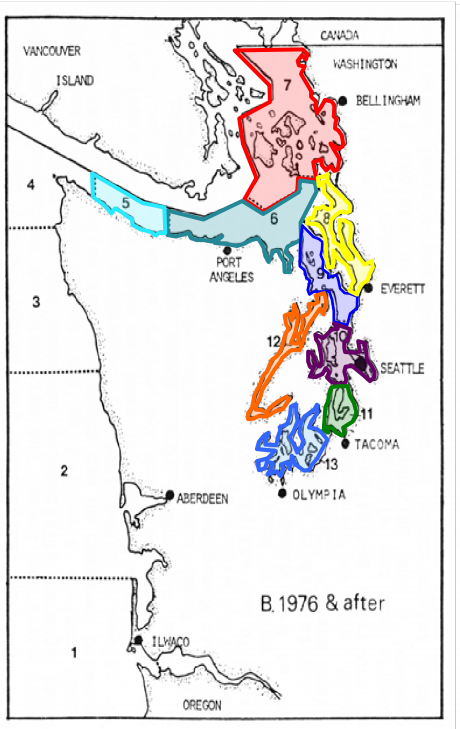




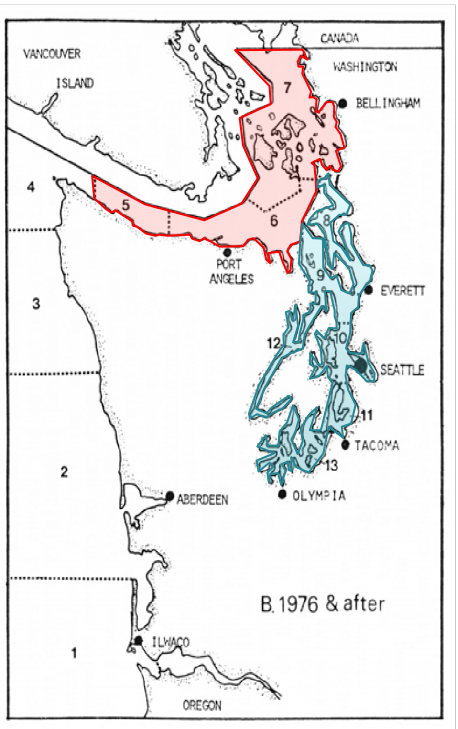
Current analysis examines spatial trends in more detail:

- Uses times series for each DPS (not an averaged by region)
- Adds data for 2008-2014

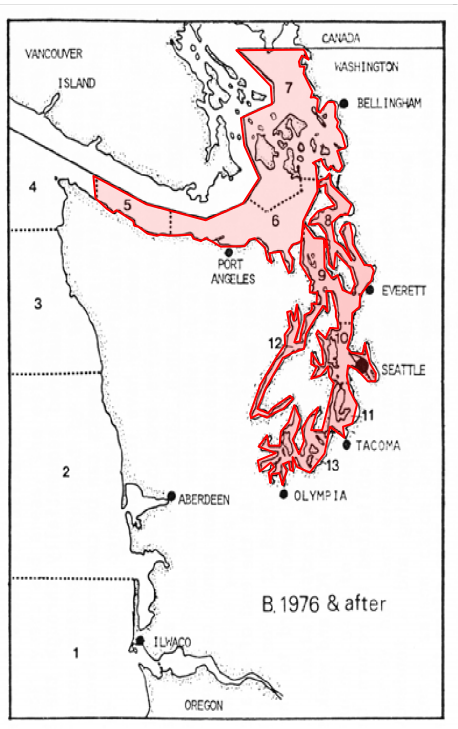
By MCA



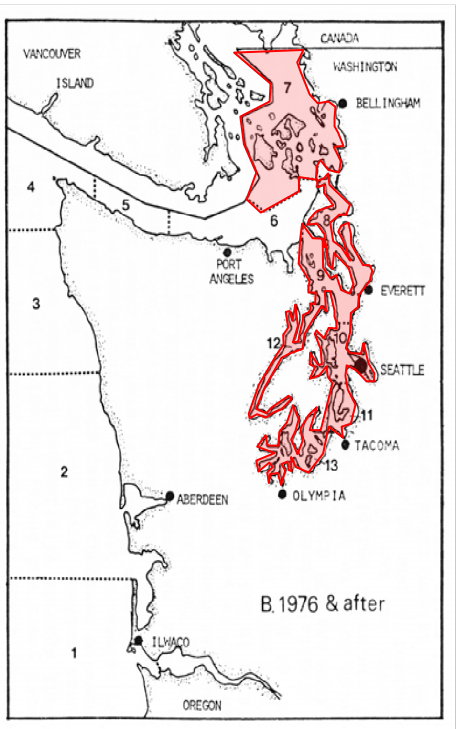
By Region



All Puget Sound

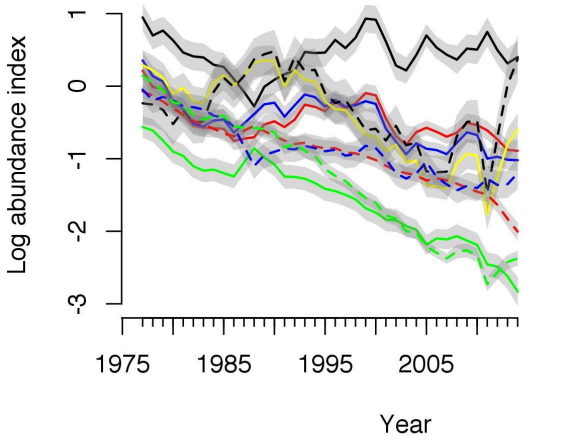


"DPS"

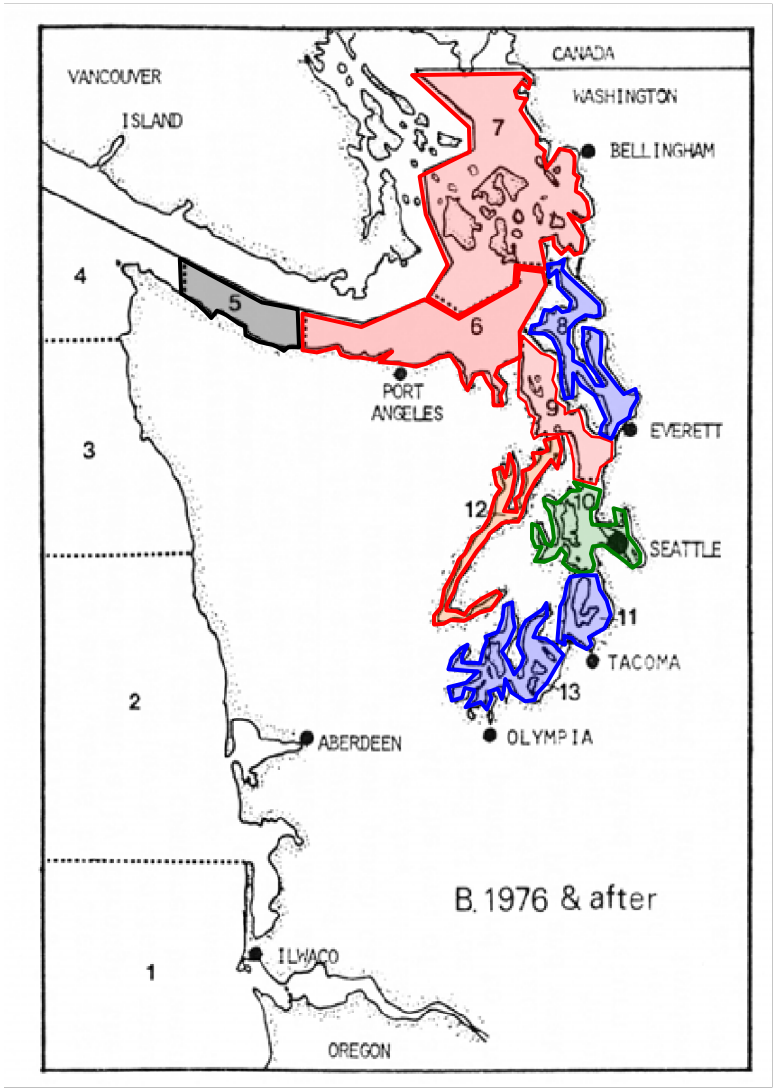


MARSS Results:

Recreational data 1977-2014



U.5	-0.015
U.6	-0.031
U.7	-0.037
U.8	-0.061
U.9	-0.024
U.10	0.017
U.11	-0.052
U.12	-0.031
U.13	-0.068



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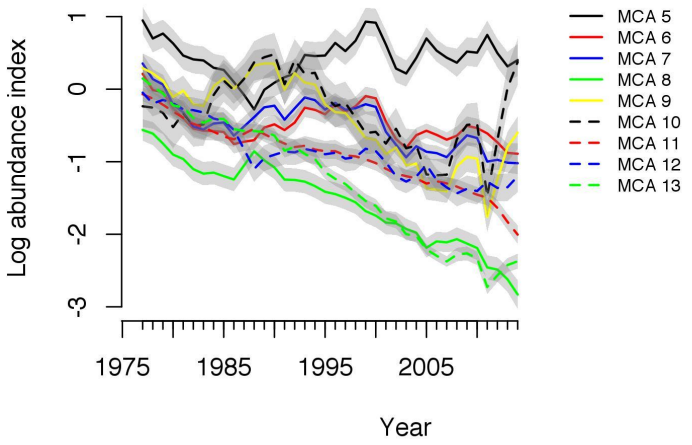

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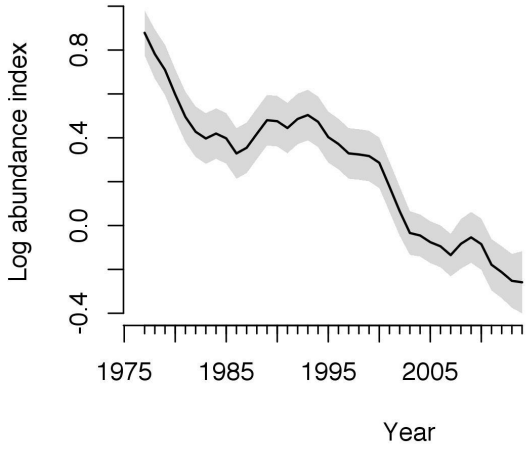
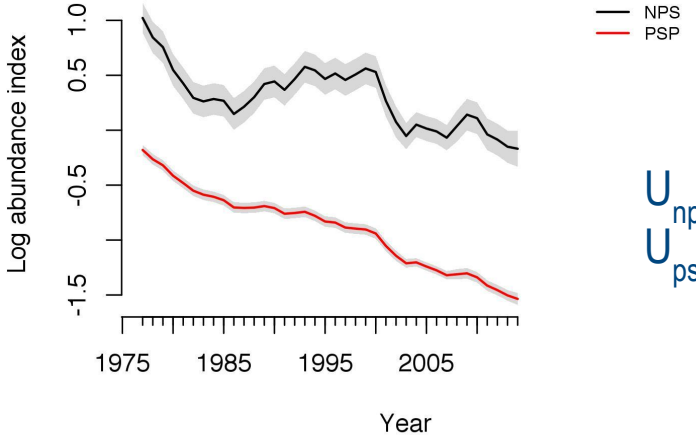
One population trend
Areas 5-13



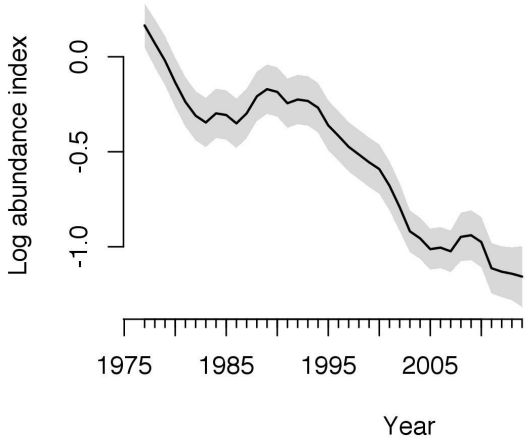
U = -0.031

Two population trends
Areas 5-13



U_{nps} = -0.032
U_{psp} = -0.037

One population trend
The DPS: Areas 7-13

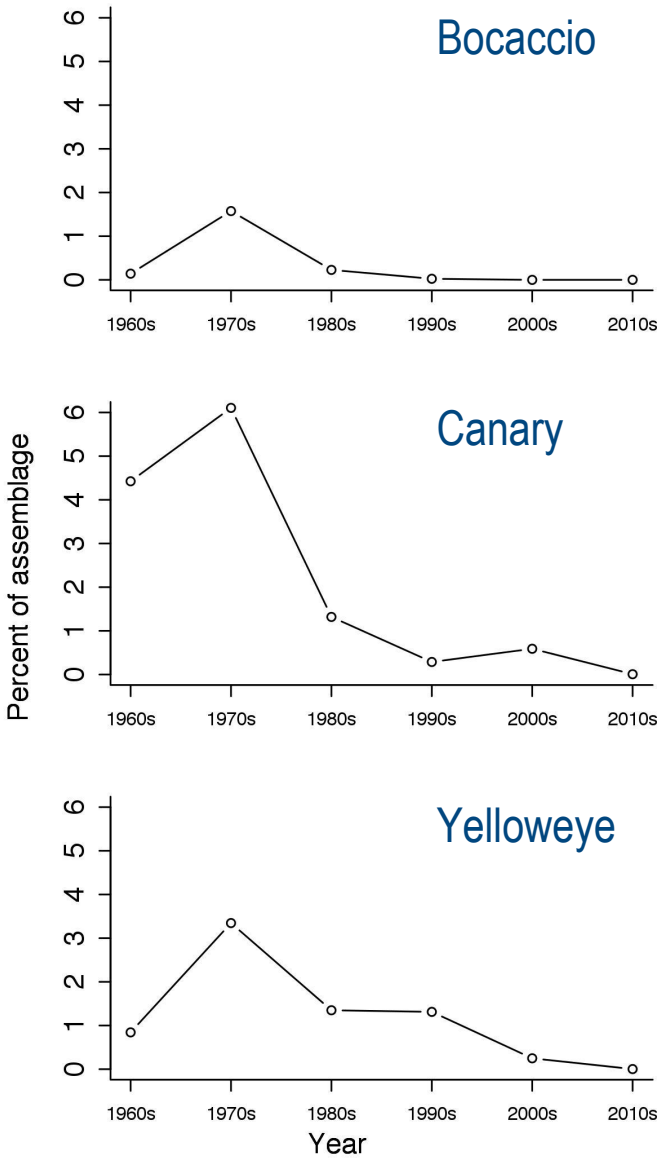


U = -0.037

Species composition by decade

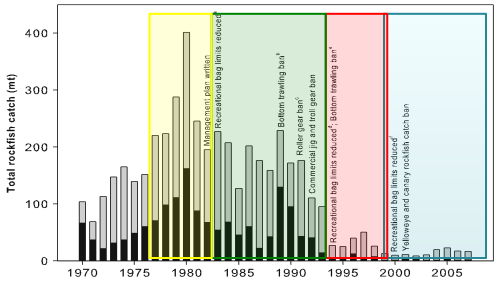
All three listed species have declined in relative abundance in the recreational catch

No recent increase



But what has happened recently?

-- Not the overall trend



$$\mathbf{x}_t = \mathbf{B}_t\mathbf{x}_{t-1} + \mathbf{u}_t + \mathbf{C}_t\mathbf{c}_t + \mathbf{w}_t$$

Process model

- c_t is normally for environmental covariates – eg PDO, ENSO
- Dummy variables to estimate
  - Slope
  - Intercept

  for each regulatory period

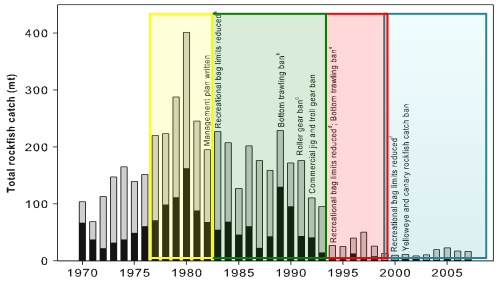
$$\mathbf{y}_t = \mathbf{Z}_t\mathbf{x}_t + \mathbf{a}_t + \mathbf{D}_t\mathbf{d}_t + \mathbf{v}_t$$

Observation model

- Has CPUE increased recently following restrictions?

* With log(y) data the process model = discrete-time Gompertz model

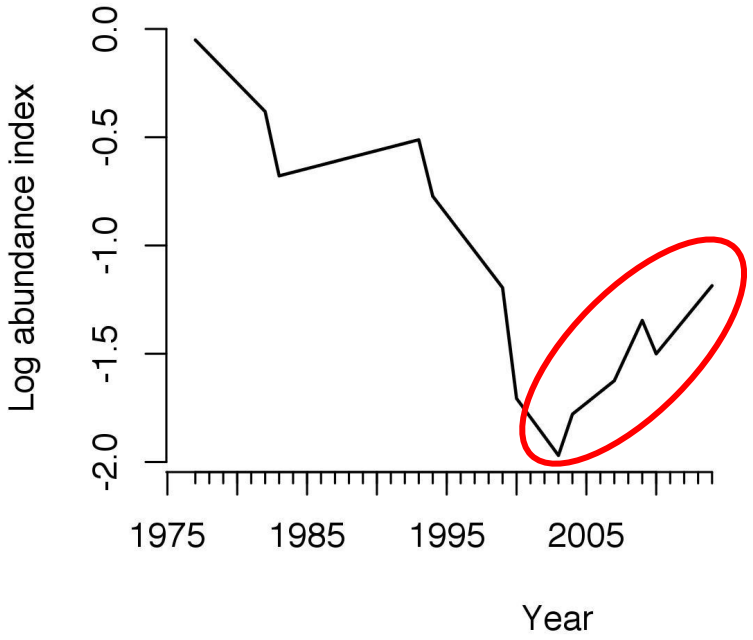
Slopes of periods with different recreational regulations (bag limits, 120 ft limit)



Increasing CPUE 2003-2014

C.(ts77) -0.066
C.(ts83) 0.017
C.(ts94) -0.085
C.(ts00) -0.088
C.(ts04) 0.139
C.(ts10) 0.079

Suggests some recovery,
at least among copper, quillback and black rockfishes which make up most of the catch



2000 = 1 fish per bag limit
2002 = no retention of canary or yellowye
2004 = change in estimation methodology
2010 = 120 ft max depth fishing limit

Two other projects

- Developing environmental DNA techniques (eDNA)
  - Just beginning

- Acoustic tracking of canary and yelloweye rockfishes
  - Canary – some small scale home range data
  - Yelloweye – study funded, but no field work yet

Where to go from here

- Genetic sampling will help to better delineate the DPS
  - For yelloweye and canary
  - No info for bocaccio
  - eDNA might help with bocaccio

- Surveys of the listed species to track recovery
  - WDFW ROV surveys in the draft recovery plan
  - Absolute abundance estimates
  - Size structure (evidence of recruitment)

- Larval sampling
  - Is there spawning
  - Is there successful reproduction?
  - Estimate of SSB

END

Extra Slides

Species composition by region 2004-2014

Species	NPS	PSP
Black	**0.7455***	0.0277
Blue	0.0031	NA
Bocaccio	**0.0009**	**NA**
Brown	0.0003	0.0196
Canary	**0.0112**	**0.0029**
China	0.0191	NA
Copper	0.0922	0.1714
Greenstriped	NA	NA
Puget Sound	NA	0.0001
Quillback	0.0561	0.0734
Redstripe	NA	NA
Sebastes spp	0.0642	**0.6311**
Tiger	0.0030	0.0005
Vermillion	0.0008	0.0013
Yelloweye	**0.0012**	**0.0009**
Yellowtail	0.0023	0.0710

* High black rockfish catch in Area 5 in the straights

Multivariate Autoregressive State Space Models (MARSS)

$$\mathbf{x}_t = \mathbf{B}_t\mathbf{x}_{t-1} + \mathbf{u}_t + \mathbf{C}_t\mathbf{c}_t + \mathbf{w}_t$$

Process model

u = population growth rate*

x_t = the state

x_{t-1} = autoregressive

w = process error

$$\mathbf{y}_t = \mathbf{Z}_t\mathbf{x}_t + \mathbf{a}_t + \mathbf{D}_t\mathbf{d}_t + \mathbf{v}_t$$

Observation model

y = the data

Z = space, time series

a = a scaling term

v = observation error

* With log(y) data the process model = discrete-time Gompertz model

Suppose you had three time series…

Z is a design matrix

One process

$$Z = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$$

Same process everywhere

Two processes

$$Z = \begin{pmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \end{pmatrix}$$

Same process in two places

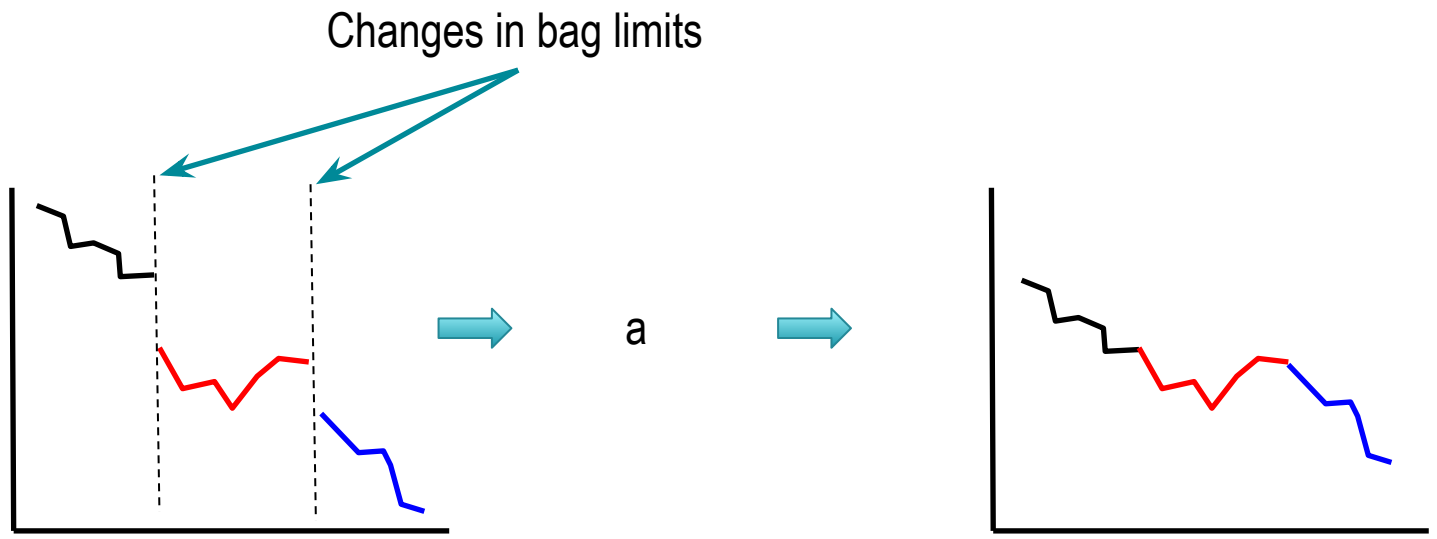
Three processes

$$Z = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Different Processes everywhere

‘a’ lets us integrate different time series?

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
TS1	0.32387205	0.65345598	0.70534728	NA	NA	NA	NA	NA	NA	NA
TS2	NA	NA	NA	0.52477606	0.52477606	0.52477606	0.52477606	NA	NA	NA
TS3	NA	NA	NA	NA	NA	NA	NA	0.52477606	0.52477606	0.52477606



Multivariate Autoregressive State Space Models (MARSS)

$$\mathbf{x}_t = \mathbf{B}_t \mathbf{x}_{t-1} + \mathbf{u}_t + \mathbf{C}_t \mathbf{c}_t + \mathbf{w}_t, \text{ where } \mathbf{w}_t \sim \text{MVN}(0, \mathbf{Q}_t)$$

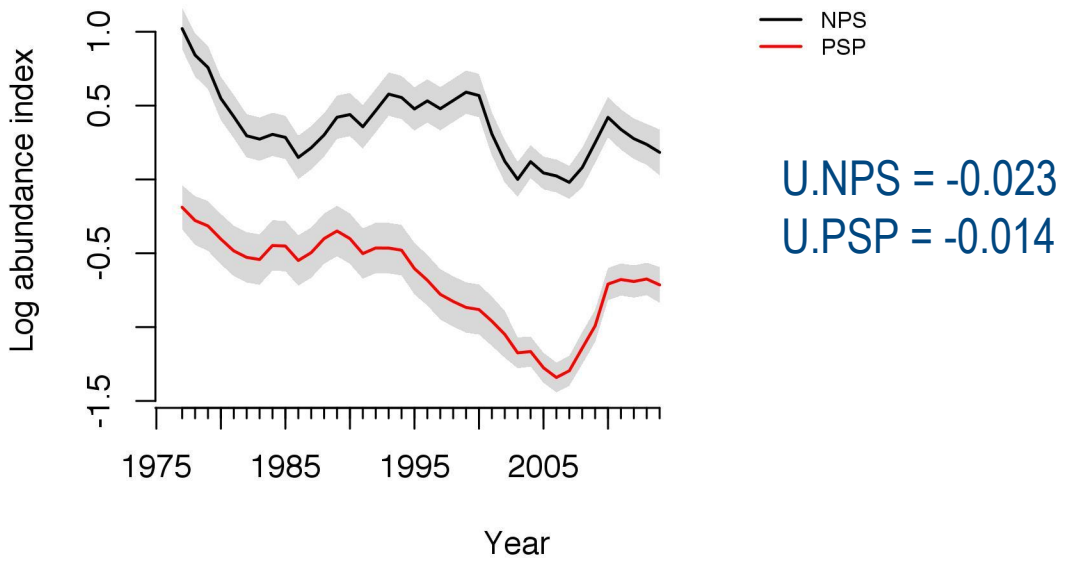
Process model

$$\mathbf{y}_t = \mathbf{Z}_t \mathbf{x}_t + \mathbf{a}_t + \mathbf{D}_t \mathbf{d}_t + \mathbf{v}_t, \text{ where } \mathbf{v}_t \sim \text{MVN}(0, \mathbf{R}_t)$$

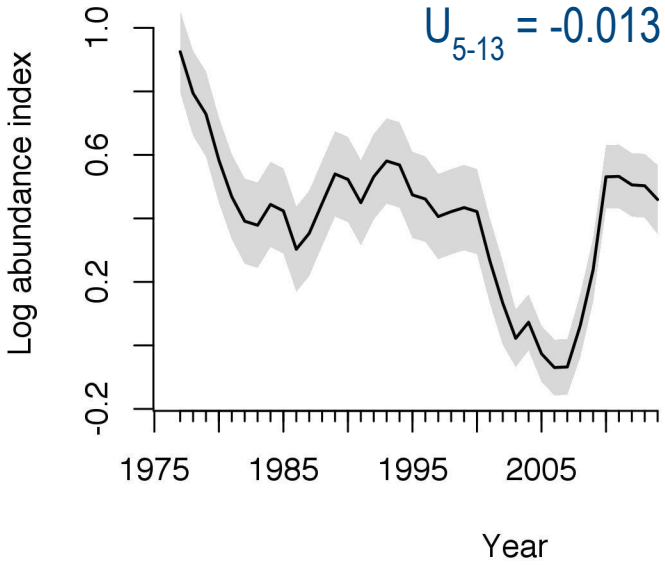
Observation model

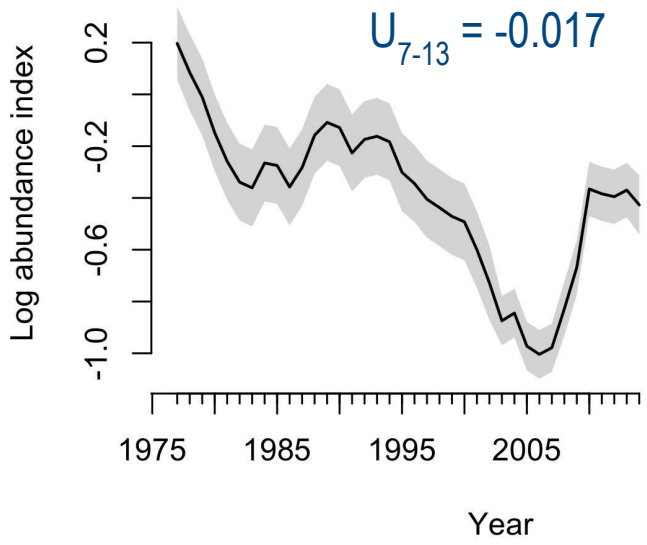
$$\mathbf{x}_1 \sim \text{MVN}(\pi, \Lambda) \text{ or } \mathbf{x}_0 \sim \text{MVN}(\pi, \Lambda)$$

Rec + REEF



U.NPS = -0.023
U.PSP = -0.014



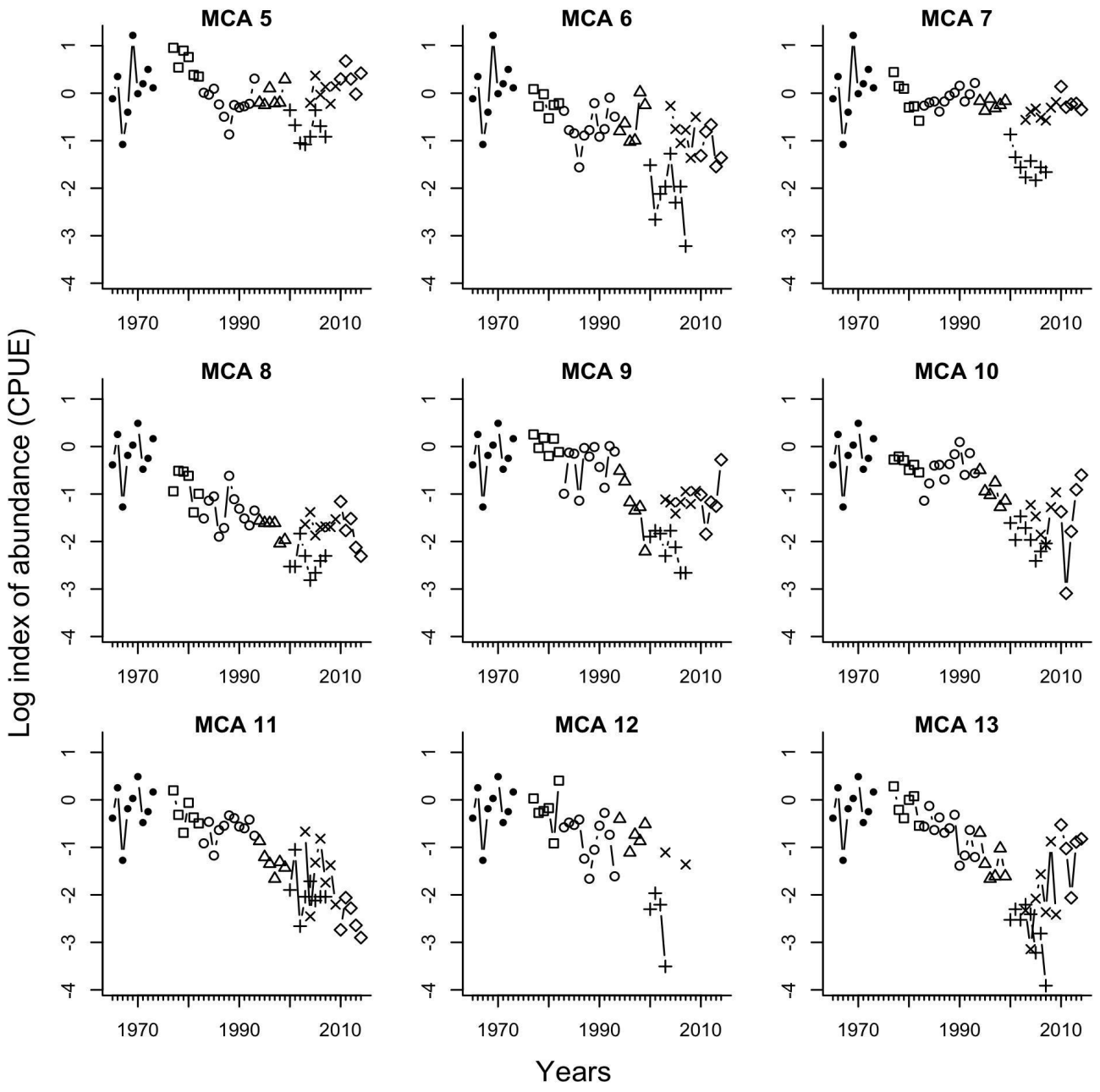


Recreational CPUE data used in the 2015 Analysis

Data are time series for each MCA

1965 – 2014

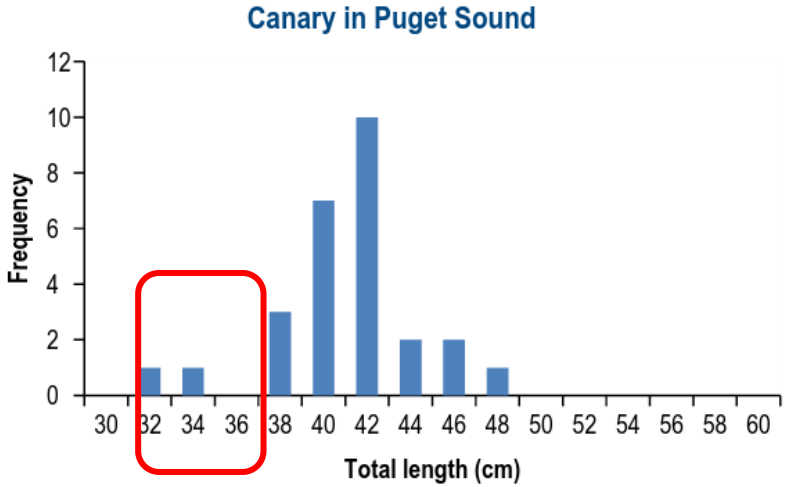
1977 – 2014 used in analysis

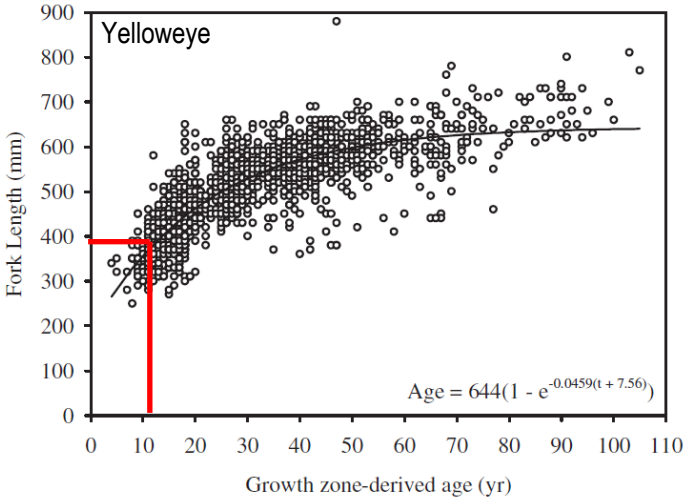


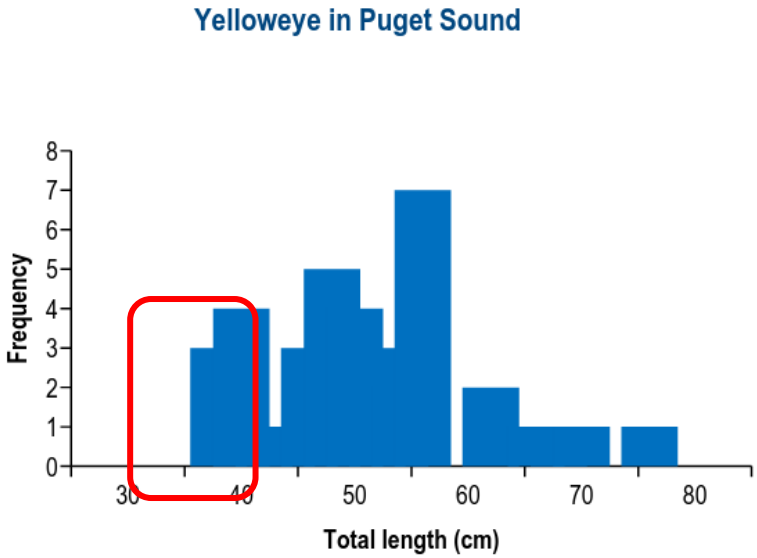
NOAA FISHERIES

Current Results

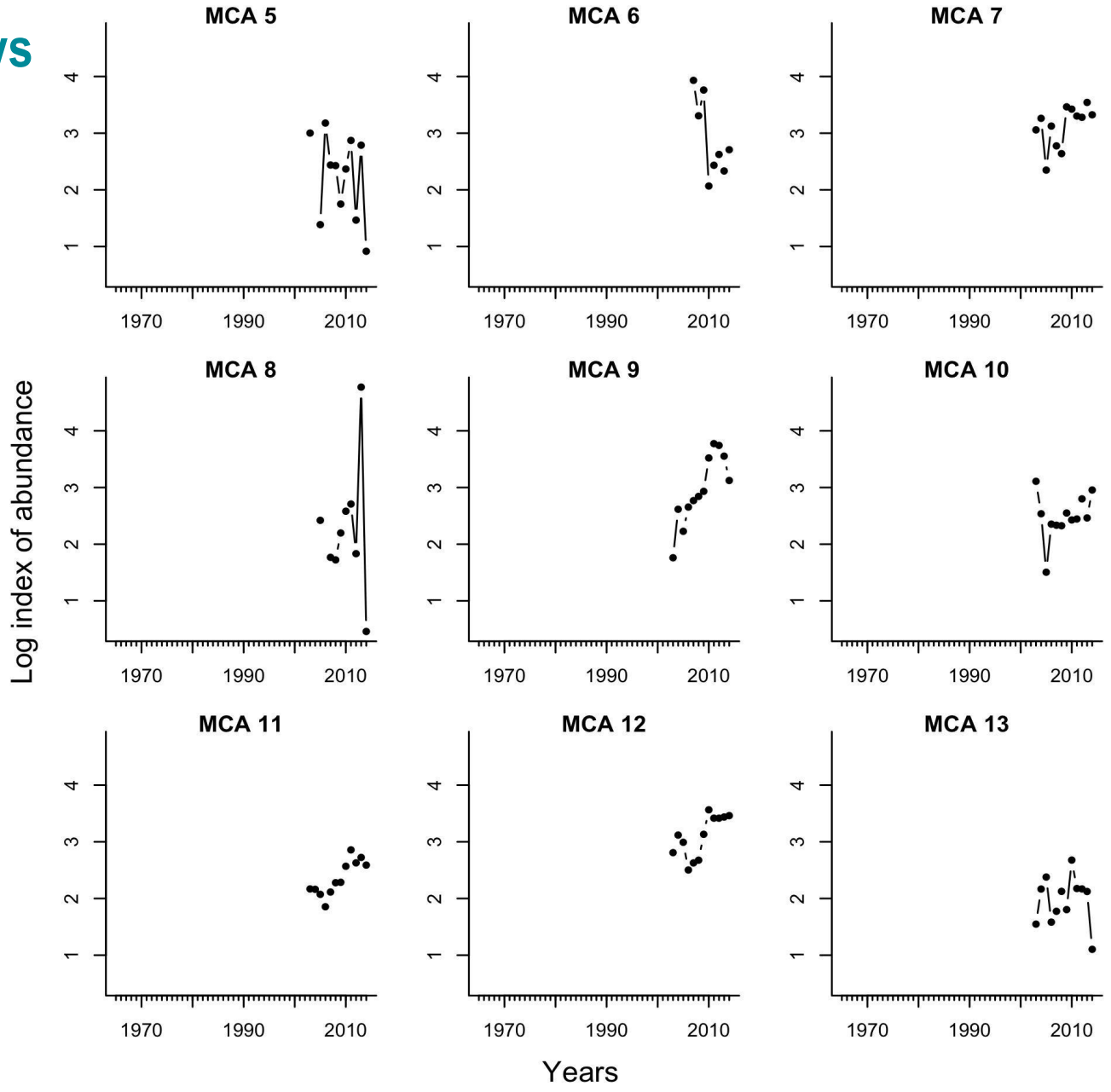
- Genetics: none, analyses are in progress
- Size frequency of the catch shows some smaller fish
  - ~ 10 yrs old for yelloweye







REEF SCUBA surveys

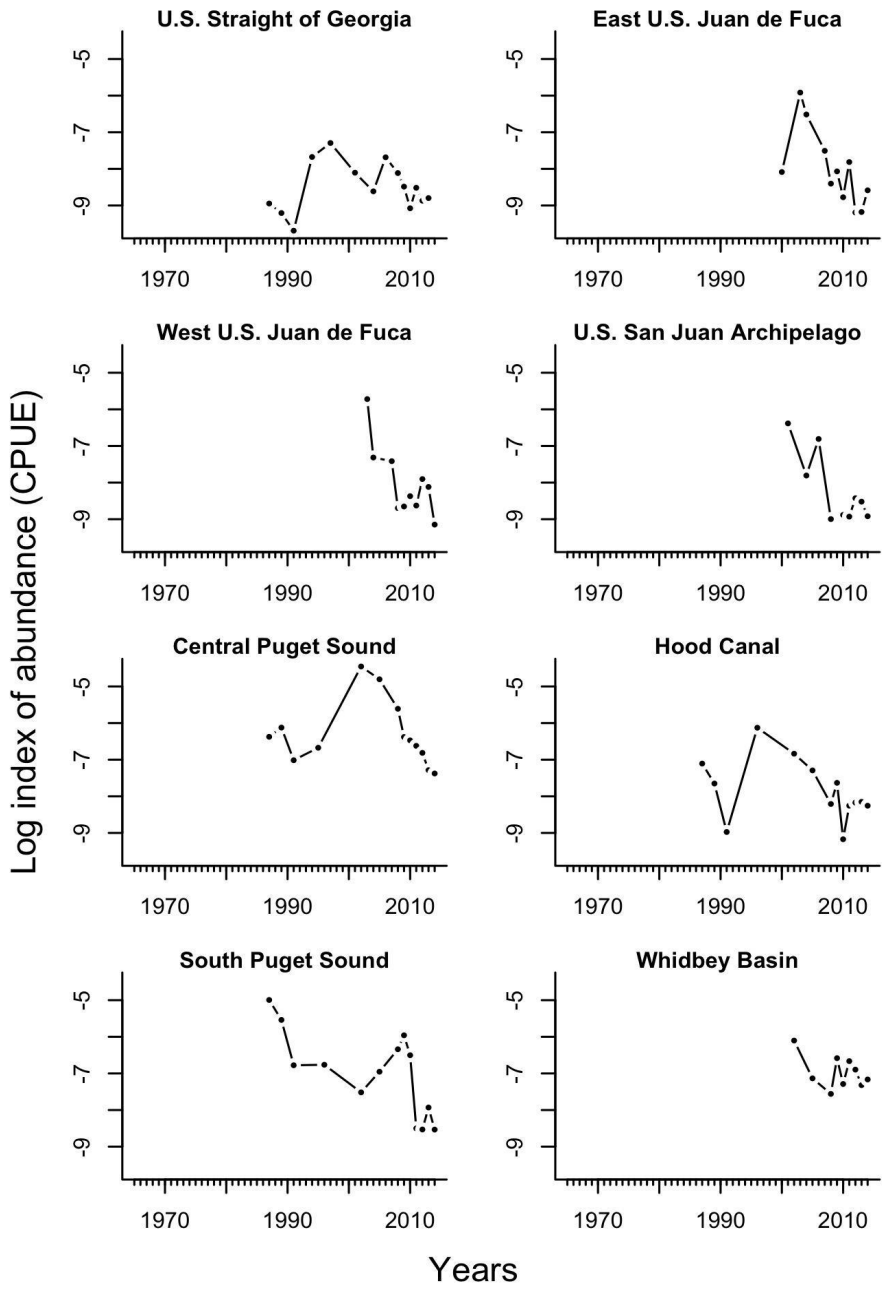


NOAA FISHERIES

Washington Department of Fish and Game Trawl Survey Data

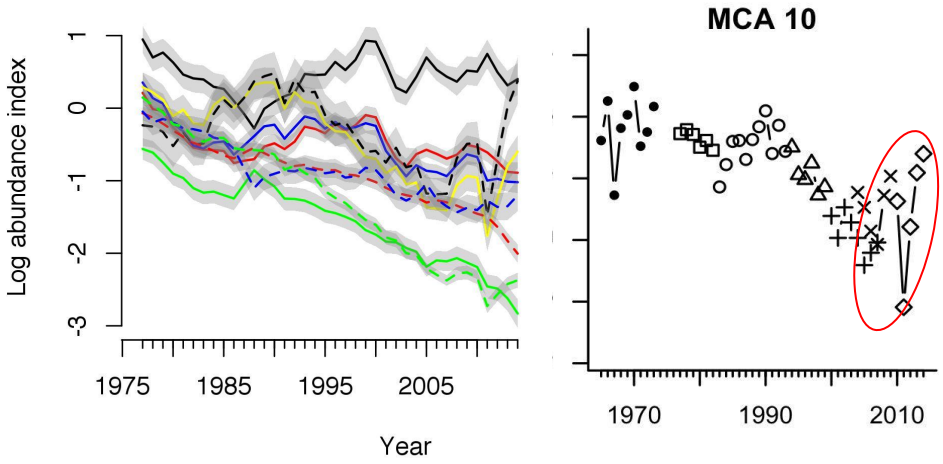
North Puget Sound

Puget Sound Proper

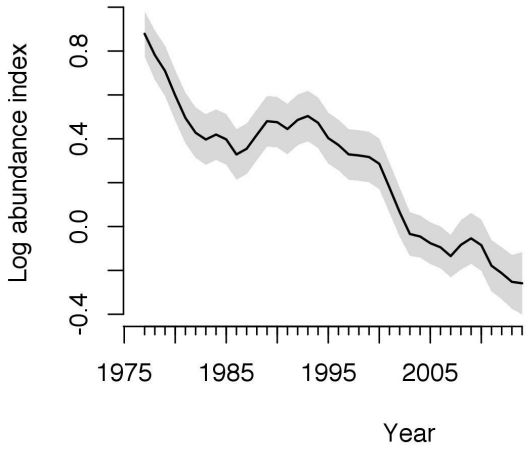


MARSS Results:

Recreational data 1977-2014

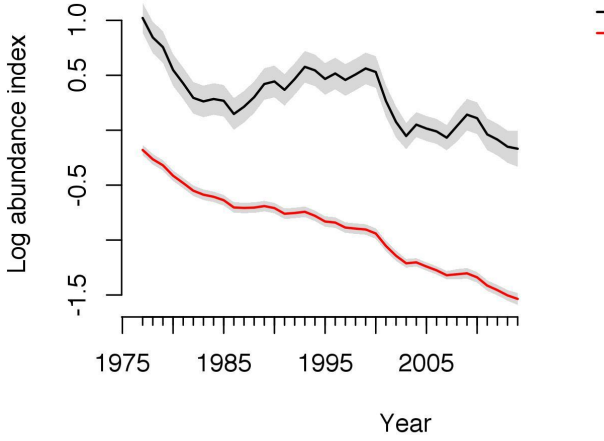


One population trend
Areas 5-13



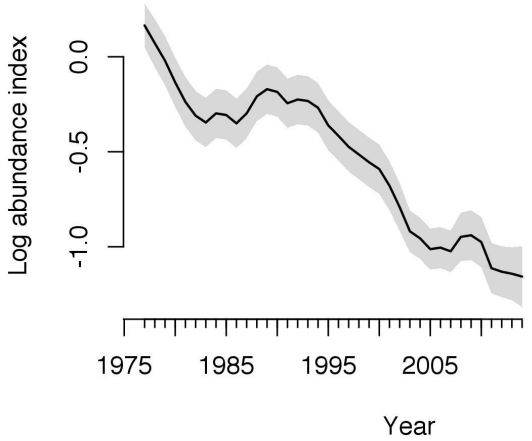
$U = -0.031$

Two population trends
Areas 5-13



$U_{nps} = -0.032$
$U_{psp} = -0.037$

One population trend
Areas 7-13



$U = -0.037$

Data collected on protected species includes:

- NOAA supported visual and acoustic surveys from ships and aircraft, including charter and unmanned platforms
- Land based field studies at both remote and local coastal sites
- Diet data, including scats, stomach contents, and biochemical data
- Genetic data to assess population structure and spatial distribution
- Tracking data from various forms of tags and telemetry
- Data from emerging technologies (e.g., autonomous vehicles, eDNA, etc.)
- Habitat use and habitat quantity and quality data, as appropriate to assess restoration actions
- Bycatch related logbook and observer data
- Stranding and entanglement information
- Captive broodstock projects to aid recovery of highly depleted stocks
- Data related to the reduction of anthropogenic takes and mortality (e.g., bycatch and harassment mitigation measures)
- Socioeconomic data as appropriate

Assessments for protected species include determination of:

- The abundance, productivity, spatial structure and diversity of protected resource stocks
- Level of take that will not impede recovery
- Interactions among listed species as predator and prey and associated trophic dynamics
- Both direct and indirect anthropogenic mortality
- Habitat restoration strategies at various spatial scales
- Effects of climate change on recovery and restoration strategies

NWFSC research projects:

- Population Genetics
  - Do PS populations differ from coastal ones?
- Developing eDNA techniques
  - Distributions, population structure, abundance(?)
- Acoustic tracking
  - Home range size
  - Is there movement between PS and the coast?
- Population trends of rockfishes in Puget Sound
  - Rate of decline?
  - Spatial structure?
  - Recent trends?

Zero impact sampling of protected species

environmental DNA

General idea:

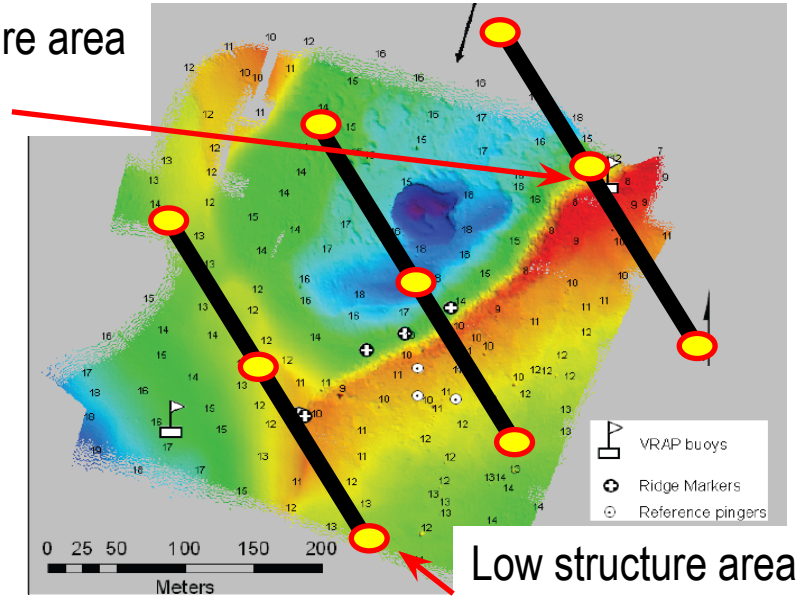
- Take water samples
- Amplify rockfish DNA
- Which species are present?
- No impact on listed species

Verification approach

- Use SCUBA surveys to quantify species assemblage around a reef
- Collect water samples at depth in the same locations
- Compare with eDNA with observed species compositions
- What spp do we miss?

Sampling locations around a reef

High structure area
Lots of fish



Low structure area
Not many fish

In progress

- Some issues with isolating rockfish DNA
- Lots of bacterial DNA
- Need to fine tune both field and lab techniques

NWFSC research projects:

- Population Genetics
  - Do PS populations differ from coastal ones?
- Developing eDNA techniques
  - Distributions, population structure, abundance(?)
- Acoustic tracking
  - Home range size
  - Is there movement between PS and the coast?
- Population trends of rockfishes in Puget Sound
  - Rate of decline?
  - Spatial structure?
  - Recent trends?

Marine Reserve Design

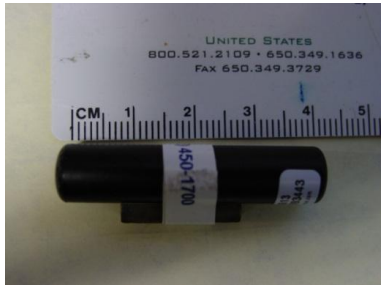
Is there a Puget Sound DPS?

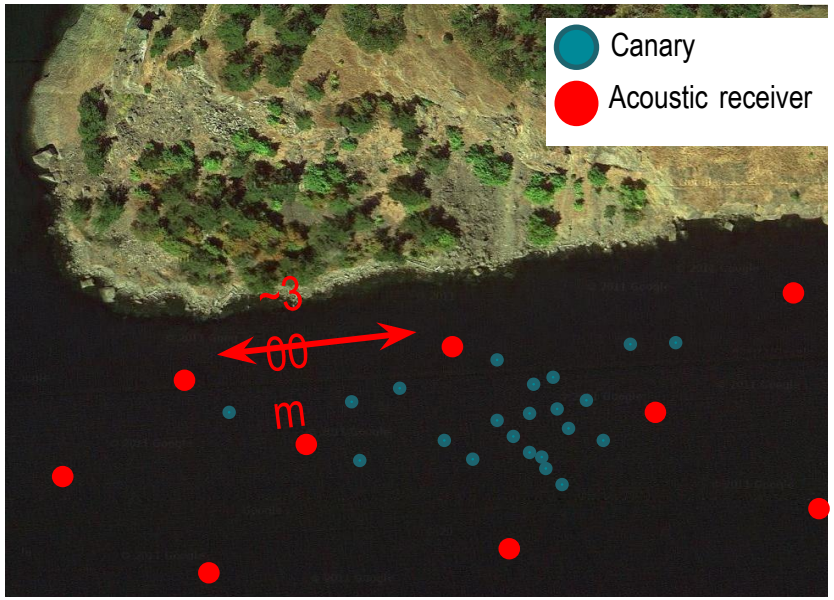
Acoustic tracking of canary rockfishes

Site fidelity

Home range (MPAs)

Movement between PS and coastal populations?

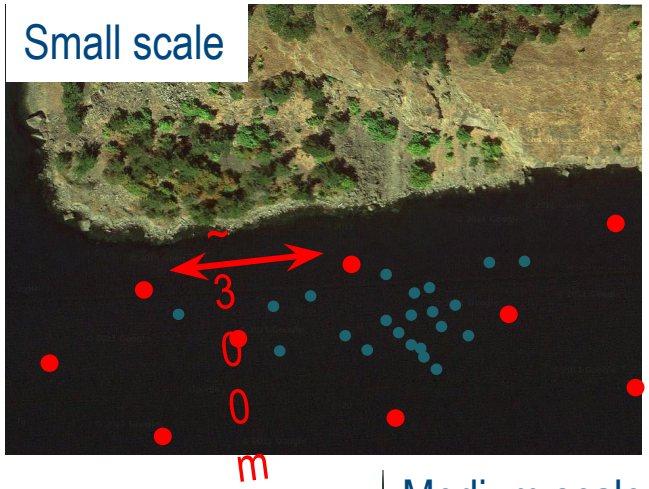




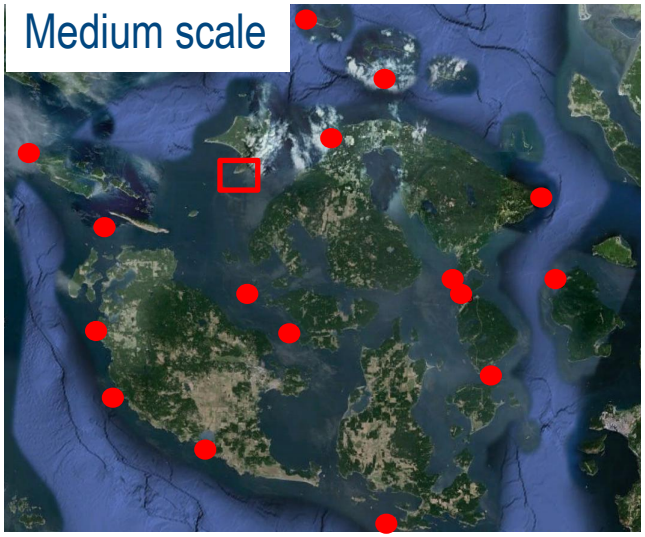
- Collect fish using hook an line sampling
- Implant an acoustic tag or “pinger”
- Track using acoustic receivers at different spatial scales

Track canary at different scales: small, medium and large arrays of receivers

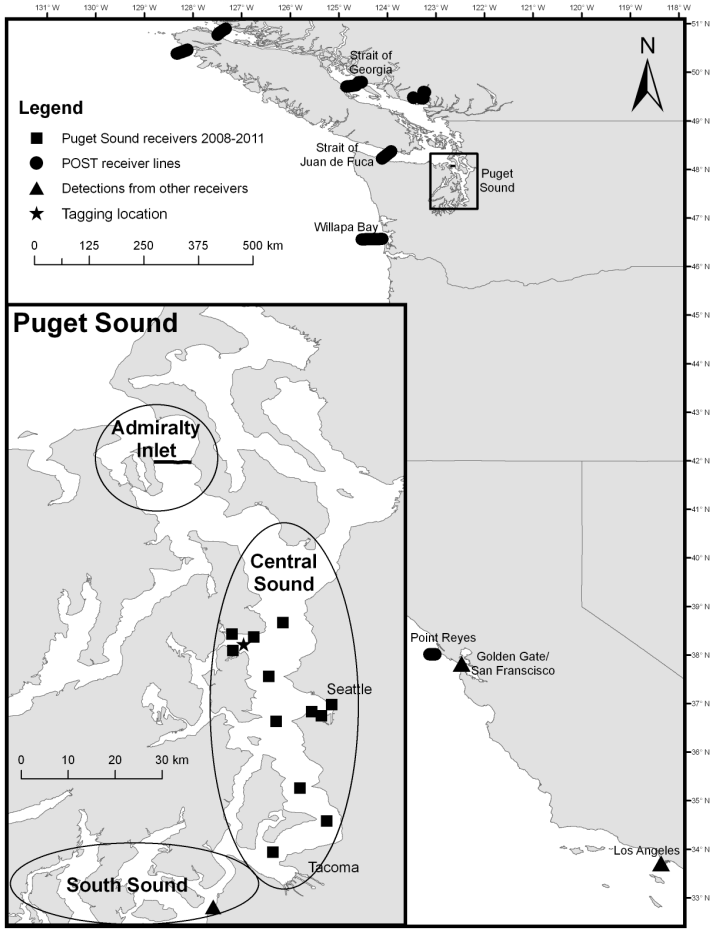
Small scale



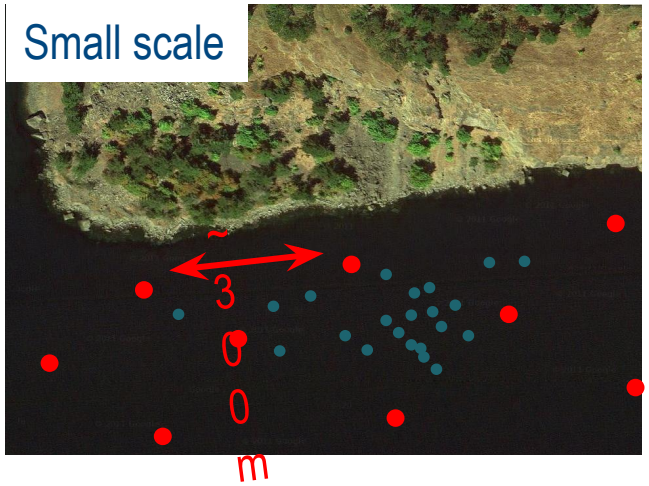
Medium scale

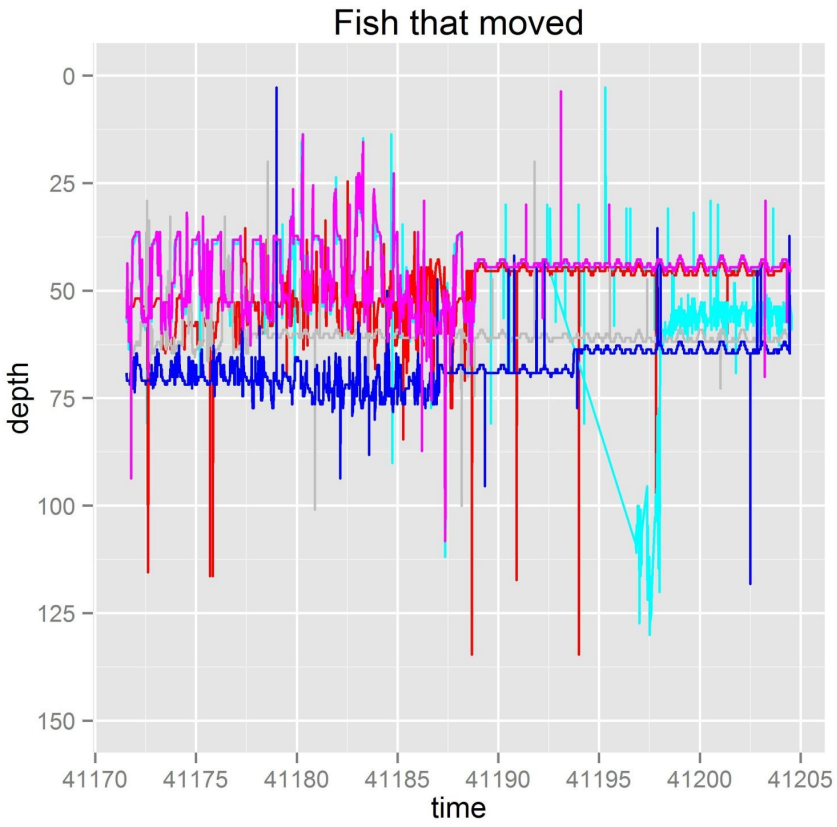


Large and larger scale



Track canary at different scales: small, medium and large arrays of receivers





...but many fish flat-lined after two weeks

Acoustic tracking of yelloweye rockfishes

- Evidence from genetics sampling that yelloweye survive the catch and release
  - Externally tagged fish seen by WDFW ROV weeks to months later, often at distant locations
- Use external ‘pingers’, lower impact, no abdominal surgery
- Funded but no field work completed yet